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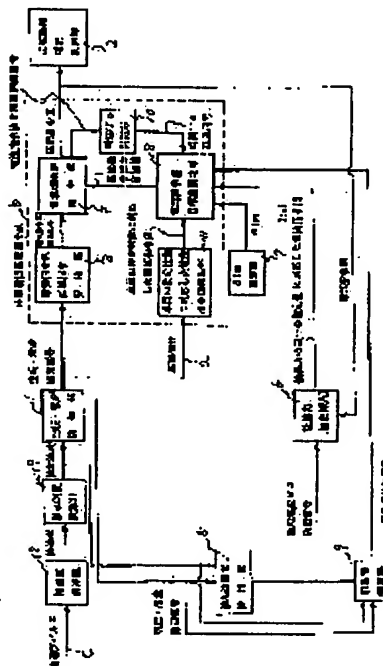
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(54) RE-ADHESION CONTROLLER FOR ELECTRIC VEHICLE

(57)Abstract:

PROBLEM TO BE SOLVED: To accurately estimate an adhesion coefficient between a wheel and a rail during the detection of slip and skid by continuing to give commands for current command value corresponding to an estimated value of the tangential force estimated by a tangential force estimating method and thereafter by increasing the current command value toward the current command value corresponding to a preset performance of the electric car.

SOLUTION: A current command generating section 4 continues to give a current command value to a tangential force estimating section 6, a re-adhesion detecting section 9 receives an axial acceleration from an axial acceleration arithmetic section 19 and outputs a re-adhesion detecting signal to a current command value target-setting section 8 on the condition that a slip and skid-detecting signal and an axial acceleration zero detection signal have been output. The current command value target setting section 8 sets the current command value, based on the current command value as a target value, corresponding to an estimated value of the tangential force outputted by the tangential force estimating section 6. As a result, the current command value generating section 4 increases the current command value at a large increasing speed toward the current command value, corresponding to the estimated value.



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CLAIMS

[Claim(s)]

[Claim 1] The axial acceleration which is the time amount differential value of the axial rate of each driving axle of electric rolling stock or a main motor shaft and an axial rate is measured or presumed. When the observed value (or estimate) of said axial acceleration exceeded the first threshold, racing (or skid) is detected. In the electric-rolling-stock control unit which the main motor current of the driving axle which reduces, the command value (or torque command value) I_p , i.e., the current command value, of a main motor current, and is in a racing (or skid) condition after detecting racing (or skid) is decreased, and is made to go to re-adhesion. After detecting racing of said driving axle in racing / skid detection section 1, the current command value (or torque command value) I_p to the main motor current control section 2 is reduced in the current command value generating section 4 in response to the command from the current command value reduction command generating section 3. The time of axial acceleration becoming zero is detected by the axial acceleration zero detecting element 5. In the tangential-force presumption section (A) 6, it is considered that said current command value (or torque command value) I_p or said observed value of a main motor current is the current command value (or torque command value) I_{p1} corresponding to the first estimate of the tangential force between the wheel and rail at the time of racing (or skid) initiation of said driving axle. Current command value ΔI_{pa} fewer than the current command value (or torque command value) I_{p1} corresponding to the first estimate of said tangential force is set up in the current command value target setting-out section (ΔI_{pa} setting-out section) 7. A current command value (or torque command value) is reduced toward this desired value as desired value of reduction of current command value (or torque command value) $I_{p1} - \Delta I_{pa}$ which is less only than this value in the current command value desired value setting-out section 8. whether the axial acceleration of said racing (or skid) shaft changed and re- (or the case of a skid — the minus side from a plus side — changing) adhered to the plus side from the minus side from the time of detecting and re-adhering by the re-adhesion detecting element 9, while making said racing (or skid) shaft go to re-adhesion. In the current command value generating section 4, it orders continuously, the current command value I_{p1} corresponding to the first estimate of said tangential force — time amount T_o — counting — until it carries out counting of the time amount T_o which can be set to arbitration in the section 10. The readhesion control approach of the electric rolling stock characterized by controlling to make it increase at the rate of buildup which can set a current command value (or torque command value) to arbitration in the current command value generating section 4 after said time amount T_o progress by making the value of the current command value generating section 11 corresponding to the setting-out engine performance of a car into desired value.

[Claim 2] After detecting racing of said driving axle in racing / skid detection section 1, the current command value (or torque command value) I_p to said main motor current control section 2 is reduced in the current command value generating section 4 in response to the command from the current command value reduction command generating section 3. The time of axial acceleration becoming zero is detected by the axial acceleration zero detecting element 5. In the tangential-force presumption section (A) 6, it is considered that said current command value (or torque command value) I_p or said observed value of a main motor current is the current command value (or torque command value) I_{p1} corresponding to the first estimate of the tangential force between the wheel and rail at the time of racing (or skid) initiation of said driving axle. Current command value ΔI_{pa} fewer than the current command value (or torque command value) I_{p1} corresponding to the first estimate of said tangential force is set up in ΔI_{pa} setting-out section 7. The current command value (or torque command value) is reduced toward this desired value as desired value of reduction of current command value (or torque command value) $I_{p1} - \Delta I_{pa}$ which is less only than this value in the current command value desired value setting-out section 8. Immediately after a current command value (or torque command value) reaches said $I_{p1} - \Delta I_{pa}$, [from] Average α_{avm} of the axial acceleration of said racing shaft in a fixed period which can be set to arbitration is calculated by the average shaft acceleration operation part 12. It detects that the axial acceleration of said racing shaft while ordering it said current command value (or torque command value) $I_{p1} - \Delta I_{pa}$ was set to α_{min} of max [absolute value / the] at the minimum value, i.e., the value of minus, by the axial acceleration minimum value detecting element 13. The current command value (or torque command value) I_{p2} corresponding to the second estimate of tangential force is calculated in the tangential-force presumption section (B) 14 by I_{p1} from aforementioned α_{min} , said current command value I_{p1} , and aforementioned $\Delta I_{pa} + [(\alpha_{min} / \alpha_{avm}) - 1]$, and ΔI_{pa} . It detects whether the axial acceleration of said racing shaft changed and re- (or the case of a skid — the minus side from a plus side — changing) adhered to the plus side from the minus side by the re-adhesion detecting element 9. Continue in the current command value generating section 4, and it orders, the current command value (or torque command value) I_{p2} corresponding to the second estimate of to [when re-adhering] said tangential force — time amount T_o — counting — until it carries out counting of the time amount T_o which can be set to arbitration in the section 10. The readhesion control approach of the electric rolling stock characterized by making it increase at the rate of buildup which can set a current command value (or torque command value) to arbitration in the current command value generating section 4 after said time amount T_o progress by making the value of the current command value generating section 11 corresponding to the setting-out engine performance of a car into desired value.

[Claim 3] When said racing shaft re-sticks after detecting racing of said driving axle in racing / skid detection section 1. In the section 10 the current command value (or torque command value) I_{p1} corresponding to the first estimate of said tangential force according to claim 1, or the current command value (or torque command value) I_{p2} corresponding to the second estimate of said tangential force according to claim 2 — time amount T_o — counting — After continuing in the current command value generating section 4 and continuing ordering until it carries out counting of the time amount T_o which can be set to said arbitration, a current command value (or torque command value) is increased according to rate-of-increase ΔI_{pi} per unit time amount of the current command value (or torque command value) which can be set to arbitration. The current command value

(or torque command value) of **** or the observed value I_p of a main motor current (t), and axial acceleration [of said driving axle] α (t) are sometimes memorized [in / from the event of beginning to increase said current command value (or torque command value) / the tangential-force presumption section (E) 15]. Re-racing (or re-skid) is detected by detecting that the axial acceleration of said re-adhesion shaft begins to increase in racing / skid detecting element (D) 16 by the rate of increase corresponding to rate-of-increase ΔI_p of said current command value. Go back from the event of carrying out re-racing (or re-skid) detection of said driving axle, and it sets in the tangential-force presumption section (E) 15. Storage value [of said axial acceleration] α (t) The current command value (or torque command value) at the time of investigating one by one and generating the increment in the axial acceleration corresponding to said rate-of-increase ΔI_p in the beginning or the storage value I_p of said observed value of a main motor current (t) is made into the current command value (or torque command value) I_{pa3} corresponding to the third estimate of tangential force. The aforementioned current command value (or torque command value) $I_{pa3} - \Delta I_{pa}$ which was set up in ΔI_{pa} setting-out section 7 from the current command value (or torque command value) I_{pa3} corresponding to the third estimate of said tangential force and then which it is less ΔI_{pa} as desired value of a current command value (or torque command value) The current command value (or torque command value) I_p is reduced toward this desired value. Detect the time of axial acceleration becoming zero by the axial acceleration zero detecting element 5, and the desired value of current (or torque) reduction is corrected to $I_{pa3} - \Delta I_{pa}$ in the current command value desired value setting-out section 8 by setting the current command value at this event (or torque command value) to I_{pa3d} . In the average shaft acceleration operation part 12 Average α_{avm1} of the axial acceleration of said racing shaft in the period which can be set to arbitration from immediately after the current command value (or torque command value) to said main motor current control section 2 reaches desired value $I_{pa3} - \Delta I_{pa}$ of the current (or torque) reduction which the above corrected is calculated. [when it detected that continued desired value $I_{pa3} - \Delta I_{pa}$ of the current (or torque) reduction which the above corrected in the axial acceleration minimum value detecting element 13, and the axial acceleration of said racing shaft under command was set to α_{min1} of max / absolute value / the / at the minimum value, i.e., the value of minus] The current command value (or torque command value) I_{pa4} corresponding to the fourth estimate of tangential force is calculated in the tangential-force presumption section (F) 17 by $I_{pa3d} + [(\alpha_{min1} / \alpha_{avm1}) - 1]$ from aforementioned α_{min1} , said I_{pa3d} , and the aforementioned ΔI_{pa} , and ΔI_{pa} . It detects whether the axial acceleration of said racing shaft changed and re-(or the case of a skid — the minus side from a plus side — changing) adhered to the plus side from the minus side by the re-adhesion detecting element 9. From the time of re-adhering The current command value (or torque command value) corresponding to the estimate of the smaller one of the current command values (or torque command value) I_{pa4} corresponding to the current command value (or torque command value) I_{pa3} corresponding to the third estimate of said tangential force, and the fourth estimate of said tangential force It orders continuously. the time amount T_o which sets up in the current command value desired value setting-out section 8, and can be set to said arbitration — time amount T_o — counting — until it carries out counting in the section 10 After said time amount T_o progress The readhesion control approach of the electric rolling stock characterized by making it increase at the rate of buildup which can set a current command value (or torque command value) to arbitration in the current command value generating section 4 by making into desired value the current command value (or torque command value) set up in the current command value generating section 11 corresponding to the setting-out engine performance of a car.

[Translation done.]

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DETAILED DESCRIPTION

[Detailed Description of the Invention]

[0001]

[The technical field to which invention belongs] This invention is the readhesion control approach of the electric-rolling-stock control unit which carries out actuation control of the main motor of electric rolling stock, and relates to the readhesion control approach of electric rolling stock of having aimed at especially the deployment of adhesion.

[0002]

[Description of the Prior Art] Although electric rolling stock is performing acceleration and deceleration according to the tangential force between a wheel and a rail (it is also called adhesion), this tangential force has the property as generally shown in drawing 10 with a broken line to sliding velocity. It is called a tangential-force multiplier including what divided by the adhesion coefficient what broke the maximum of this tangential force by the axle load (normal load which joins the rail per axle 1 shaft), and divided the other tangential force by the axle load. When the torque which does not exceed the maximum of tangential force like a graphic display is generated with the main motor, racing and a skid are not generated but electric rolling stock runs with the minute sliding velocity shown with the broken line on the left of the maximum of tangential force. Since sliding velocity will be in racing / skid condition that sliding velocity increases increasingly since it increases and tangential force declines, but the engine performance of a car will be set up so that the torque which a wheel and a rail generate with a main motor in dryness may not exceed the maximum of tangential force if larger torque than maximum is generated, racing and a skid are not generated.

[0003] However, as a continuous line shows, when a rail level is in a damp or wet condition by rain etc., an adhesion coefficient falls and the maximum of tangential force becomes smaller than the generating torque of the main motor corresponding to the setting-out engine performance of a car. In this case, it is needed to reduce the torque which detects racing and a skid promptly since tangential force will decline corresponding to this if sliding velocity increases, and it will be in a racing condition and is left as it is, and acceleration force required for acceleration of a car declines increasingly, and a main motor generates, and to make it re-adhere. Thus, controlling [control torque and] to small sliding velocity, when making it re-adhere, it is required to control so that the generating torque of a main motor becomes a value near the maximum of tangential force as much as possible, when raising the acceleration-and-deceleration engine performance of electric rolling stock.

[0004] While detecting the rotational frequency (rotational speed) of a main motor and detecting racing and a skid as an approach aiming at implementation of such readhesion control after this in quest of the time amount rate of change, i.e., acceleration When the current pattern of a main motor is reduced with the time constant corresponding to the axial acceleration of the main motor shaft at the time of racing / skid detection, re-adhesion is aimed at and a racing shaft begins to go to re-adhesion, there is the approach of returning torque with the time constant corresponding to the axial acceleration at that time.

[0005] Moreover, there is the readhesion control approach it was made to generate the torque corresponding to the adhesion coefficient which presumed the adhesion coefficient and was presumed after re-adhesion with a main motor by presuming a fallen part from the adhesion coefficient corresponding to the main motor torque at that time from driving axle acceleration as an option at the time of racing generating.

[0006]

[Problem(s) to be Solved by the Invention] However, by the former approach, since the time constant of reduction and buildup of torque is set up according to the situation when going to the time of racing detection, and re-adhesion, since extent in change of a actual adhesion coefficient corresponds and can do a torque control, it may be able to aim at a deployment of adhesion.

However, if resetting of a control parameter is not carried out when there is no guarantee which is surely adapted and can be controlled even when an adhesion coefficient changes how, and an adhesion coefficient changes with the charge railroad section of electric rolling stock, weather conditions, etc. broadly since the tangential force corresponding to an adhesion coefficient is not necessarily presumed, sliding velocity will become large, and the case where a deployment of adhesion cannot be aimed at occurs. Moreover, since the moment of inertia of the circumference of the driving axle seen on the driving wheel periphery when the wheel diameter of a driving wheel became small since a fallen part of an adhesion coefficient was presumed from the product of the axial acceleration of a driving axle and the moment of inertia of a driving axle in the case of the latter approach changes, there is a trouble that the presumed error of an adhesion coefficient occurs corresponding to this.

[0007] Even if it be in solve these faults and an adhesion coefficient change broadly, the place which this invention be originated in view of the point mentioned above, and be make into the object always presume the adhesion coefficient between the wheel and rail at the time of racing / skid detection with a sufficient precision, and be to offer the readhesion control approach of the electric rolling stock which can use effectively the adhesion which do not need adjustment of a control parameter.

[0008]

[Means for Solving the Problem] That is, the means for attaining the object is set to one claim 1. While ordering it the current command value (or torque command value) corresponding to the setting-out engine performance of a car, when racing or a skid is detected, after racing or skid detection, In the process in which reduce the current command value (or torque command value) of a main motor current, and a racing shaft is made to go to re-adhesion It is considered that the current command value (or torque command value) at the time of the racing rate of the event of the axial acceleration of a racing shaft becoming zero, i.e., a racing shaft, changing to reduction or the observed value of a current is the current command value (or torque command value) I_{p1} corresponding to the estimate of tangential force (the first tangential-force presumption approach). The current command value (or torque command value) of a main motor current is reduced to $I_{p1}-\Delta I_{p1}$ which is more slightly [than the current command value (or torque command value) I_{p1} corresponding to the estimate of the tangential force presumed by this first

tangential-force presumption approach] less only than ΔI_{pa} . After a current command value (or torque command value) reaches $I_{pa1} - \Delta I_{pa}$, ordering it this $I_{pa1} - \Delta I_{pa}$ is continued. During the period T_o which axial acceleration changes to a plus side from a minus side, and can set to arbitration from the event of re-(changing to a minus side from a plus side in a skid) adhering. Ordering it the current command value (or torque command value) I_{pa1} corresponding to the estimate of the tangential force presumed by the first tangential-force presumption approach is continued. It is made by having the approach of increasing the aftercurrent command value (or torque command) towards the current command value (or torque command) corresponding to the setting-out engine performance of a car.

[0009] 2) While ordering it the current command value (or torque command value) corresponding to the setting-out engine performance of a car, when racing or a skid is detected in claim 2 In the process in which reduce the current command value (or torque command value) of the main motor current after racing or skid detection, and a racing shaft is made to go to re-adhesion By said first tangential-force presumption approach, it is considered that the current command value (or torque command value) at the time of the axial acceleration of a racing shaft becoming zero or the observed value of a current is the current command value (or torque command value) I_{pa1} corresponding to the estimate of tangential force. The current command value (or torque command value) of a main motor is reduced to $I_{pa1} - \Delta I_{pa}$ which is more slightly [than this I_{pa1}] less only than ΔI_{pa} . After a current command value (or torque command value) reaches $I_{pa1} - \Delta I_{pa}$, ordering it this $I_{pa1} - \Delta I_{pa}$ is continued. Average shaft acceleration α_{avm} in the period which can be set to the arbitration immediately after reaching $I_{pa1} - \Delta I_{pa}$ is calculated. From minimum value α_{amin} of the axial acceleration of a racing shaft while ordering it $I_{pa1} - \Delta I_{pa}$, after that By $I_{pa1} + (\alpha_{amin} / \alpha_{avm}) - 1$ and ΔI_{pa} It is considered that the calculated correcting current command value (or torque command value) is the current command value (or torque command value) I_{pa2} corresponding to the estimate of the maximum (namely, tangential force corresponding to an adhesion coefficient) of tangential force (the second tangential-force presumption approach). During the period T_o which axial acceleration changes to a plus side from a minus side, and can set to arbitration from the event of re-(changing to a minus side from a plus side in a skid) adhering. Ordering it the current command value (or torque command value) I_{pa2} corresponding to the maximum of the tangential force searched for by the second tangential-force presumption approach is continued. It has the approach of increasing the aftercurrent command value (or torque command value) towards the current command value (or torque command value) corresponding to the setting-out engine performance of a car.

[0010] 3) In claim 3 Current command value corresponding to the estimate of the tangential force presumed by the first tangential-force presumption approach (or torque command value) Current command value corresponding to the estimate of the tangential force presumed by I_{pa1} or the second tangential-force presumption approach (or torque command value) I_{pa2} After axial acceleration changes to a plus side and continues ordering from a minus side during the period T_o which can be set to arbitration from the event of re-(changing to a minus side from a plus side in a skid) adhering. Increase a current command value (or torque command value) by a certain rate of increase, and it goes. The current command value (or torque command value) of **** or the observed value of a main motor current, and axial acceleration are sometimes held after the event of beginning to make a current command value (or torque command value) increase. It makes to detect re-racing, when the increment in axial acceleration is observed by the rate of increase corresponding to the rate of increase of a current command value (or torque command value) in this current command value (or torque command value) buildup process into the second racing detection approach. When it goes back from the event of detecting re-racing and the increment in axial acceleration starts first by the second racing detection approach A ***** command value (or torque command value) or observed value I_p of a main motor current (t) It considers as the current command value (or torque command value) I_{pa3} corresponding to the estimate of tangential force (the third tangential-force presumption approach). The current command value (or torque command value) to a main motor is reduced by making into desired value $I_{pa3} - \Delta I_{pa}$ which is more slightly [than the current command value (or torque command value) I_{pa3} corresponding to the estimate of the tangential force presumed by the third presumed approach] less only than ΔI_{pa} . The desired value of current (or torque) reduction is corrected to $I_{pa3} - \Delta I_{pa}$ by setting the current command value (or torque command value) at the time of axial acceleration becoming zero to $I_{pa3} - \Delta I_{pa}$. Average shaft acceleration α_{avm1} in the period which can be set to arbitration immediately after a current reaches desired value $I_{pa3} - \Delta I_{pa}$ of a current command value (or torque command value) is calculated. From minimum value α_{amin1} of the axial acceleration of a racing shaft while ordering it $I_{pa3} - \Delta I_{pa}$, after that When the correcting current command value (or torque command value) calculated by $I_{pa3} + (\alpha_{amin1} / \alpha_{avm1}) - 1$ and ΔI_{pa} is made into the current command value (or torque command value) I_{pa4} corresponding to the estimate of tangential force (the fourth tangential-force presumption approach) and racing settled and re-sticks It is ordered the current command value (or torque command value) of the smaller one of the current command values (or torque command value) I_{pa3} and I_{pa4} corresponding to the estimate of the tangential force presumed by the third and fourth tangential-force presumption approach during said period T_o . After the period passes, it has the approach of increasing a current command value (or torque command value) towards the current command value (or torque command value) corresponding to the setting-out engine performance of a car by a certain rate of increase.

[0011]

[Embodiment of the Invention] Hereafter, the readhesion control approach of the electric rolling stock by this invention is explained to a detail using the example of a graphic display. Drawing 1 is the explanatory view of the change situation of the tangential force between the torque or the torque command value change corresponding to the current command value [according / drawing 3 / to the example of drawing 1] according [the block diagram and drawing 2 which show the example of this invention according to claim 1] to the explanatory view of the example of this invention according to claim 1 of operation, and a wheel and a rail. In addition, only the case of racing is explained below. In a skid, since it does not change fundamentally in addition to this only by becoming the case where change of an axial rate and axial acceleration is racing, and reverse, it omits. In drawing 1 -3, the train operation dispatching a from the master controller which is not illustrated is inputted into the main motor current command system (or a torque command system: make it represent with a current command system below) b. The current command value (or a torque command value: make it represent with a current command value below) corresponding to the setting-out engine performance of a car is generated in the current command value generating section 11 corresponding to the setting-out engine performance of a car, and it outputs to the current command value desired value setting-out section 8. In connection with this, current command value ΔI_{pa} smaller than the current command value corresponding to the setting-out engine performance of a car (or torque command value), i.e., the current command value corresponding to the estimate of tangential force, is set up in the current command value desired value setting-out section 7 (ΔI_{pa} setting-out section).

[0012] The axial rate pulse c from the rate sensor attached in the driving axle or main motor shaft which is not illustrated on the other hand is inputted into the axial rate operation part 18, an axial rate calculates, the calculated axial rate is inputted into the axial acceleration operation part 19, and axial acceleration calculates it. Subsequently to racing / skid detection section 1, axial

acceleration is inputted. The adhesion coefficient between a wheel and a rail like [at the time of rail desiccation] in being sufficiently large Since racing / skid detection signal which is the output of racing / skid detection section 1 since axial acceleration does not reach the threshold of racing / skid detection is not outputted and a current command value reduction signal is not generated at the current command value reduction command generating section 3 In the current command value generating section 4, ordering the main motor current control section 2 the current command value corresponding to the setting-out engine performance of the car set up in the current command value desired value setting-out section 8 is being continued (condition before the time of day to of drawing 2).

[0013] Subsequently, if an adhesion coefficient becomes small by a rainfall etc. and the tangential force between a wheel and a rail becomes smaller than the torque generated in the main motor (time of day to of drawing 2), racing will occur, a driving axle will be accelerated and axial acceleration will come (time of day t1 of drawing 2) to exceed a threshold. At this event, racing / skid detecting element 1 of drawing 1 detects racing, and racing / skid detection signal is outputted. In the current command value reduction command generating section 3, if racing / skid detection signal is inputted, since a current command value reduction signal will be generated, in the current command value generating section 4, a current command value is decreased at a certain reduction rate. The racing rate of a racing shaft begins to decrease by this. Therefore, axial acceleration also decreases, the **** acceleration zero point is passed soon, and it becomes minus shaft acceleration. So, in the axial acceleration zero detecting element 5 into which the axial acceleration from the axial acceleration operation part 19 is inputted, when the axial acceleration inputted the condition [racing / skid detection signal having been outputted] is investigated and axial acceleration serves as zero (time of day t11 of drawing 2), an axial acceleration zero detecting signal is outputted to the tangential-force presumption section (A) 6.

[0014] In the tangential-force presumption section (A) 6, it considers that the current command value inputted from the main motor current command system at the time of receiving an axial acceleration zero detecting signal is the estimate of the tangential force at that time, and this is outputted as a current command value Ipa1 corresponding to the first estimate of tangential force. And in order to make a racing shaft re-stick certainly, Ipa1-deltaIpa which subtracted the above-mentioned deltaIpa set up in deltaIpa setting-out section 7 is set up in the current command value desired value setting-out section 8 as desired value of current command value reduction. As a small value, this deltaIpa avoids that the amount of reduction of a current command value becomes large in vain as much as possible by within the limits to which a racing shaft can be made to re-adhere certainly.

[0015] In the current command value generating section 4, if a current command value reaches this desired value Ipa1-deltaIpa (time of day t2 of drawing 2), maintaining a current command value to this desired value Ipa1-deltaIpa is continued. A racing shaft re-sticks by this. At this time, axial acceleration passes zero again from a minus side, and changes to a plus side at it. So, in the re-adhesion detecting element 9, when the axial acceleration from the axial acceleration operation part 19 is inputted and axial acceleration passes zero from a minus side (time of day t3 of drawing 2), a re-adhesion detection signal is outputted to the current command value desired value setting-out section 8 a condition [racing / skid detection signal and the axial acceleration zero detecting signal having been outputted]. If this re-adhesion detection signal is received in the current command value desired value setting-out section 8, since the current command value Ipa1 corresponding to the estimate of the tangential force which the tangential-force presumption section (A) 6 outputted previously will be set up as desired value In the current command value generating section 4, a current command value is increased toward the current command value Ipa1 corresponding to the first estimate at the big buildup rate as much as possible within the limits which do not induce pitching motion of the control turbulence of a main motor current control system, or a truck.

[0016] and event (time of day t31 of drawing 2) of a current command value reaching the above Ipa1 a current command value upper-limit attainment signal — time amount To — counting — while outputting to the section 10, a current command value is maintained to Ipa1. and — if fixed period To progress is carried out (time of day t4 of drawing 2) — time amount To — counting — the section 10 outputs a time amount To progress signal to the current command value desired value setting-out section 8. By this, since the current command value desired value setting-out section 8 sets up the current command value corresponding to the setting-out engine performance of the car at that time, in the current command value generating section 4, toward this desired value, it increases a current command value at a buildup rate which does not injure a degree of comfort, and ends control. The die length of the above-mentioned period To is the constant value which can be set to arbitration. If To is lengthened not much, an adhesion coefficient will change between them, and by having ordered it above Ipa1, deviation is produced between actual values. Moreover, what is necessary is just to set up in consideration of these points, since loss of the tangential force by which racing and re-adhesion are repeated frequently and the effect (effect of deltaIpa) by reduction of the current command value for making it re-adhere is used for acceleration of electric rolling stock by becoming large will increase if it shortens too much not much.

[0017] Event of axial acceleration becoming zero to the beginning, when it was good, and racing detectability ability can detect racing while the racing rate was small as shown in drawing 3 (time of day t11 of drawing 2) The current command value Ipa1 is a value very near the tangential force corresponding to an adhesion coefficient. Therefore, however it will order it torque only with small delta Ipa, after re-adhesion will order it Ipa1 which is a value very near the tangential force corresponding to an adhesion coefficient and an adhesion coefficient may change slightly in process of [Ipa / 1] re-adhesion by performing the above control, since it is maintainable to the tangential force near the adhesion coefficient at that time, a deployment of adhesion can be aimed at.

[0018] Drawing 4 is the explanatory view of the change situation of the tangential force between the torque or the torque command value change corresponding to the current command value [according / drawing 6 / to the example of drawing 4] according [the block diagram and drawing 5 which show the example of this invention according to claim 2] to drawing of the example of claim 2 of this invention of operation, and a wheel and a rail. The place where the example of drawing 4 differs from the example of claim 1 of drawing 1 A current command value lower limit attainment signal is added from the current command value generating section 4 of a main motor current command system. Moreover, average shaft acceleration alphaavm which are the average shaft acceleration operation part 12, the axial acceleration minimum value detecting element 13, the tangential-force presumption sections (B) 14, and those outputs, It is that the signal of minimum shaft acceleration alphaamin and the current command value (or torque command value) Ipa2 corresponding to the second estimate of tangential force is added.

[0019] While it is ordered the current command value corresponding to the setting-out engine performance of a car and electric rolling stock is running as well as the case of drawing 1 in drawing 4 , an adhesion coefficient falls suddenly and racing starts (time of day to of drawing 5). If it becomes after that more than the threshold of racing detection of axial acceleration and racing is detected (time of day t1 of drawing 5), will output racing / skid detection signal by racing / skid detecting element 1 at this

event, and by the main motor current command system, if racing / skid detection signal is inputted When a current command value is decreased at a certain reduction rate, the axial acceleration inputted by the axial acceleration zero detecting element 5 the condition [racing / skid detection signal having been outputted] is investigated and axial acceleration serves as zero (time of day t11 of drawing 5) An axial acceleration zero detecting signal is outputted to the tangential-force presumption section (A) 6.

[0020] In the tangential-force presumption section (A) 6, it considers that the current command value inputted from the main motor current command system at the time of receiving an axial acceleration zero detecting signal is the estimate of the tangential force at that time, and this is outputted as a current command value I_{pa1} corresponding to the estimate of tangential force. And in order to make a racing shaft re-stick certainly, I_{pa1} -delta I_{pa} which subtracted delta I_{pa} set up in delta I_{pa} setting-out section 7 is outputted to a main motor current command system as desired value of current command value reduction. As a small value, this delta I_{pa} avoids that the amount of reduction of a current command value becomes large in vain as much as possible by within the limits to which a racing shaft can be made to re-adhere certainly. By the main motor current command system, a current command value is reduced until a current command value reaches this desired value I_{pa1} -delta I_{pa} . The control by the above place is the same as drawing 1 .

[0021] In drawing 4 , when a current command value decreases even to I_{pa1} -delta I_{pa} (time of day t2 of drawing 5), in the current command value generating section 4, a current command value lower limit attainment signal is outputted to the average shaft acceleration operation part 12. And a current command value is maintained by I_{pa1} -delta I_{pa} . In the average shaft acceleration operation part 12, average shaft acceleration signal α_{avm} which is the average is calculated based on the axial acceleration inputted during a fixed period it can be determined to arbitration that receives a current command value lower limit attainment signal (period from the time of day t2 of drawing 5 to t21). although axial acceleration passes zero again from a minus side and changes to a plus side, when it is continued by maintaining that aftercurrent command value I_{pa1} -delta I_{pa} and a racing shaft re-sticks — this event (time-of-day t3t of drawing 5) up to — in between, minimum shaft acceleration α_{amin} is detected in the axial acceleration minimum value detecting element 13 (in the time of day t22 of drawing 5 , axial acceleration becomes min) . And it is the current command value I_{pa2} on the tangential-force presumption section (B) 14 from average shaft acceleration α_{avm} and minimum shaft acceleration α_{amin} , and corresponding to the second estimate of tangential force (1) It calculates by the formula.

[0022] $I_{pa2} = I_{pa1} + [(\alpha_{min}/\alpha_{avm}) - 1]$ and delta I_{pa} .. (1)

[0023] If sliding velocity decreases in the process in which order it I_{pa1} -delta I_{pa} and the racing shaft is going to re-adhesion as shown in drawing 6 , the tangential force between a wheel and a rail will increase. And when axial acceleration is set to minimum value α_{amin} (time of day t22 of drawing 5) α_{amin} has axial acceleration equivalent to the difference of the tangential force corresponding to the adhesion coefficient between the wheel and rail at that time, and the tangential force corresponding to current command value I_{pa1} -delta I_{pa} . Therefore, I_{pa2} calculated from (1) type is a current command value corresponding to the adhesion coefficient at that time. Here, when presuming the adhesion coefficient of a racing shaft according to (2) types using axial acceleration like the conventional technique, if the wheel diameter of a driving wheel becomes small by re-profiling of a wheel etc. as shown also in (3) types, the error of estimate will occur. In addition, for the driving wheel periphery upper coating tension in which a main motor generates F_t by (2) and (3) formulas, the inertial mass of the driving axle and drive system which saw M_j on the driving wheel periphery, and J , the moment of inertia of the circumference of a driving axle and r are [driving axle acceleration and F_m of the radius of a driving wheel and α] tangential force.

[0024] $F_m = F_t - M_j - \alpha$ (2)
 $M_j = J/(r-r)$ (3)

[0025] On the other hand, when the current command value corresponding to an adhesion coefficient is calculated by (1) type ($\alpha_{min}/\alpha_{avm}$) Since the effect which changes an inertial mass by calculating is removed, even if the diameter of a driving wheel becomes small, an adhesion coefficient can be presumed with a sufficient precision., In drawing 4 , the current command value I_{pa2} corresponding to the second estimate of the tangential force presumed in the tangential-force presumption section (B) 14 is again outputted to the current command value desired value setting-out section 8. Moreover, if a re-adhesion detecting signal is outputted by the re-adhesion detecting element 9 after that (time of day t3 of drawing 5), since the current command value I_{pa2} corresponding to the second estimate of tangential force will be set up in the current command value desired value setting-out section 8, in the current command value generating section 4, a current command value is increased toward I_{pa2} . and the event (time of day t22 of drawing 5) of a current command value reaching the above I_{pa2} — a current command value upper limit attainment signal — time amount T_o — counting, since it is outputted to the section 10 If only a fixed period T_o continues ordering it I_{pa2} and T_o passes in him [field / of drawing 1] (time of day t4 of drawing 5), a current command value will be increased toward the current command value corresponding to the setting-out engine performance of the car at that time, and control will be ended.

[0026] As shown in drawing 6 , racing detection sensitivity is low, a racing rate becomes large, and racing detection is carried out (after it follows and tangential force declines considerably). Since the tangential force corresponding to the adhesion coefficient in front of re-adhesion can be presumed with a sufficient precision by (2) types even when torque low loss in quantity becomes large rather than the case where it is shown in drawing 3 It will be mostly ordered the current command value corresponding to the adhesion coefficient at that time at the time of re-adhesion, and the readhesion control approach which can use adhesion effectively can be offered at it.

[0027] Drawing 7 is the explanatory view of the change situation of the tangential force between the torque or the torque command value change corresponding to the current command value [according / drawing 9 / to the example of drawing 7] according [the block diagram and drawing 8 which show the example of this invention according to claim 3] to the explanatory view of the example of this invention according to claim 3 of operation, and a wheel and a rail. The place where the example of drawing 7 according to claim 3 differs from the example of claim 2 of drawing 4 racing — a skid — a detecting element — (— D —) — 16 — tangential force — presumption — the section — (— E —) — 15 — tangential force — presumption — the section — (— F —) — 17 — and Re-racing / skid detection signal which are these outputs, It is that the current command value (or torque command value) I_{pa3} corresponding to the third estimate of tangential force, the current command value (or torque command value) I_{pa4} corresponding to the fourth estimate of tangential force, and current command value I_{pa3d} at the time of axial acceleration zero detection are added.

[0028] In drawing 7 , the re-adhesion detection signal from the re-adhesion detecting element 9 will be set in the current

command value generating section 4 during the aforementioned period To from this event (time of day t3 of drawing 8), if it receives in a main motor current command system. Either of the current command values Ipa2 corresponding to the estimate of the second tangential force presumed in the current command value Ipa1, corresponding to the estimate of the first tangential force when it presumed in the example according to claim 1, and the example according to claim 2 continues, and it is ordered. And it is made to increase by the rate of increase which consists of an event (time of day t4 of drawing 8) of carrying out period To progress deltaIp by making into desired value the current command value corresponding to the setting-out engine performance of a car in which a current command value can be acquired from the car rate at that time. this — the time — sometimes — **** — a driving axle — acceleration — alpha — (— t —) — a current — a command — a value — or — a main motor — a current — observed value — Ip — (— t —) — racing — a skid — detection — the section — (— D —) — 16 — and — tangential force — presumption — the section — (— E —) — 15 — setting — memorizing — having. Even if a current command value increases and the generating torque of a main motor increases, when a driving axle is in an adhesion condition, sliding velocity hardly changes but axial acceleration changes in accordance with the acceleration of a car.

[0029] That is, it changes with a value almost equal to average shaft acceleration α_{aav} between the time of day t3 of drawing 8 - t4. Then, if it shifts to a racing condition from an adhesion condition according to buildup of torque, buildup of the axial acceleration corresponding to rate-of-increase deltaIp of a current command value will come to be continuously observed for every control period. Then, in racing / skid detection section (D) 16 of drawing 7, when buildup of this axial acceleration comes to be observed continuously (time of day t41 of drawing 8), re-racing is detected, and re-racing / skid detection signal is outputted. Thus, if buildup of axial acceleration detects racing in the buildup process of a current command value, racing is detectable to the inside of a minute racing rate.

[0030] Next, if this re-racing / skid detection signal is outputted, in the tangential-force presumption section (E) 15, from this event, would go back in the past and storage value [of axial acceleration] alpha (t) will be investigated one by one. The current command value at the time of generating the increment in the axial acceleration corresponding to above rate-of-increase deltaIp or the storage value Ip of the observed value of a main motor current (t) is outputted to the beginning as a current command value Ipa3 corresponding to the third estimate of the tangential force at the time of racing generating. In addition, when re-racing is not detected even if it increased the current command value by the above-mentioned approach, but the current command value corresponding to the setting-out engine performance of a car is reached, readhesion control is ended at the event.

[0031] If the current command value Ipa3 corresponding to the third estimate of tangential force is outputted, since Ipa3-deltaIp which subtracted only set point delta Ip of deltaIp setting-out section 6 from Ipa3 will be set up in the current command value desired value setting-out section 8, in the current command value generating section 4, a current command value is reduced by making Ipa3-deltaIp into desired value. And current command value Ipa3d at the time of receiving the axial acceleration zero detecting signal from the axial acceleration zero detecting element 5 in the tangential-force presumption section (F) 17 (time of day t51 of drawing 8) is outputted. If Ipa3d is outputted, since the desired value of current reduction will be corrected to Ipa3 d-delta Ip which subtracted only set point delta Ip of deltaIp setting-out section in the current command value desired value setting-out section 8, in the current command value generating section 4, reducing a current command value even to above-mentioned correction desired value Ipa3 d-delta Ip is continued. And when a current command value decreases to Ipa3 d-delta Ip (time of day t61 of drawing 8), in the current command value generating section 4, a current command value lower limit attainment signal is outputted to the average shaft acceleration operation part 12 as well as an example according to claim 2. And a current command value is maintained by Ipa3 d-delta Ip.

[0032] During a fixed period it can be determined to arbitration in the average shaft acceleration operation part 12 that receives a current command value lower limit attainment signal (period from the time of day t6 of drawing 8 to t61) Average shaft acceleration signal α_{aavm1} which is the average is calculated based on the inputted axial acceleration. although axial acceleration passes zero again from a minus side and changes to a plus side, when it is continued by maintaining that aftercurrent command value Ipa3 d-delta Ip and a racing shaft re-sticks — this event (time of day t7 of drawing 8) up to — in between, minimum shaft acceleration α_{amin1} is detected in the axial acceleration minimum value detecting element 13 (in the time of day t62 of drawing 8, axial acceleration becomes min). and — an average — a shaft — acceleration — alpha — avm — one — min — a shaft — acceleration — alpha — min — one — from — tangential force — presumption — the section — (— F —) — 17 — setting — tangential force — the — four — estimate — having corresponded — a current — a command — a value — Ipa — four — (4) types — calculating — a main motor current command system — receiving — outputting.

[0033]

$$Ipa4 = Ipa3d + [(\alpha_{amin1} / \alpha_{aavm1}) - 1] - (\delta Ip)$$

.... (4)

[0034] If a re-racing shaft re-sticks and axial acceleration passes zero again from a minus side, a re-adhesion detection signal will be outputted by the re-adhesion detecting element 9 (time of day t7 of drawing 8). At this event, in the current command value desired value setting-out section 8, since the current command value of the smaller one of the current command values Ipa4 corresponding to the current command value Ipa3 corresponding to the third estimate of tangential force and the fourth estimate of tangential force is set up as desired value, in the current command value generating section 4, a current command value is increased toward this desired value. and event (time of day t71 of drawing 8) of a current command value reaching the above-mentioned current command value of the smaller one from — only a fixed period To continues ordering it the current command value of the smaller one. It is made to increase by the rate of increase it will become Ip like the event of being the time of day t4 of drawing 8 delta [rate of increase] by making into desired value the current command value corresponding to the setting-out engine performance of a car in which a current command value can be acquired from the car rate at that time if To passes. If racing / skid detection section D16 of drawing 7 does not detect re-racing even if it increases a current to the current command value corresponding to the setting-out engine performance of a car, readhesion control is ended there. If re-racing is detected, the actuation after the time of day t4 of drawing 8 will be repeated.

[0035] If it is ordered only Ipa3, choosing the current command value of the smaller one of the current command values Ipa4 corresponding to the current command value Ipa3 corresponding to the third estimate of tangential force, and the fourth estimate of tangential force as desired value as mentioned above When the current command value corresponding to the actual tangential force at the time of re-racing detection is smaller than the current command value Ipa3 which was ordering it only the period To before it increases a current command value, (Since it is not set to three or less Ipa even if it calculates the current command value corresponding to the estimate of the tangential force at the time of re-racing initiation at the time of re-racing detection). Since it may become the situation which racing expands gradually, it is for preventing this. By ordering it the smaller one of Ipa3 and Ipa4 as mentioned above, without expanding racing also to the condition of generally at the time of the rainfall that an

adhesion coefficient falls with lifting of a train rate etc. being observed, gradually, it can always be ordered the current command value corresponding to a presumed adhesion coefficient, and a car can be accelerated.

[0036] Although the change situation of the tangential force between a wheel and a rail is indicated to be the torque at the time of controlling a current command value by the example according to claim 3 to drawing 9, or a torque command value change (for a thick continuous line to show) Since buildup of the axial acceleration corresponding to the amount of buildups of a current command value detects re-racing in the buildup process of a current command value as stated also in advance, racing can be detected to the inside of a minute racing rate, therefore a deployment of adhesion is attained more.

[0037] It is as follows when the readhesion control approach of the above this invention is summarized.

(1) In the example according to claim 1, while ordering it the current command value corresponding to the setting-out engine performance of a car, when racing / skid detection sensitivity can detect racing and a skid to the inside of a high and small racing rate by the case where racing and a skid are detected It is considered that a current command value in case driving axle acceleration becomes zero, reducing a current command value is the estimate I_{pa1} of the tangential force at the time of racing / skid detection. Reduce a current command value to $I_{pa1} - \Delta I_{pa}$, it is made to go to re-adhesion, and control which increases a current command value by the rate of increase which has turned I_{pa1} to a certain current command value corresponding to [continue carrying out a fixed period command and] the setting-out engine performance of the car at that time after fixed period progress promptly after re-adhesion is performed.

[0038] (2) In the example according to claim 2, while ordering it the current command value corresponding to the setting-out engine performance of a car, when racing / skid detection sensitivity detects racing and a skid to the inside of a low and large racing rate by the case where racing and a skid are detected It is considered that a current command value in case driving axle acceleration becomes zero, reducing a current command value is the estimate I_{pa1} of the tangential force at the time of racing / skid detection. Reduce a current command value to $I_{pa1} - \Delta I_{pa}$, make it go to re-adhesion, and ordering it the current command value I_{pa2} corresponding to the estimate of the tangential force in front of re-adhesion, i.e., the tangential force corresponding to an adhesion coefficient, is continued between a certain 1 commuter's tickets. Control which increases a current command value by the rate of increase turned to the current command value corresponding to the setting-out engine performance of the car at that time is performed after fixed period progress.

[0039] (3) case where racing and a skid are detected in the process which is increasing the current command value in the example according to claim 3 on the other hand by the rate of increase turned to the current command value corresponding to the setting-out engine performance at that time (namely, when re-racing and a skid are detected) The current command value at the event of the beginning to which the axial acceleration of a driving axle continues increasing [come] by the rate of increase corresponding to the rate of increase of a current command value It is regarded as the current command value I_{pa3} corresponding to the estimate of the tangential force at the time of re-racing / skid initiation. When a current command value is reduced as desired value and axial acceleration becomes zero on the way about $I_{pa3} - \Delta I_{pa}$ in it, the desired value of current command value reduction is corrected to $I_{pa3} - \Delta I_{pa}$ using current command value I_{pa3d} at that time. Reduce a current command value to $I_{pa3d} - \Delta I_{pa}$, and it is made to make it re-stick. Ordering it the current command value I_{pa4} corresponding to the tangential force in front of re-adhesion (namely, tangential force corresponding to an adhesion coefficient) and the current command value of the smaller one of the above I_{pa3} is continued between a certain 1 commuter's tickets after re-adhesion. Control which increases a current command value by the rate of increase turned to the current command value corresponding to the setting-out engine performance of the car at that time is performed after fixed period progress.

[0040] Although the current command value at that time was used, you may make it use the observed value of the current at that time for this in the above example as $I_{pa1} - I_{pa4}$ it is considered that are a current command value corresponding to the estimate of the tangential force at the time of racing / skid detection. Moreover, when a driving axle rate can be presumed from the electrical potential difference and current of a main motor, you may make it use the axial acceleration calculated based on this presumed shaft rate like the inverter car using the induction motor as a main motor, although the axial acceleration calculated and called for based on the observed value of an axial rate as axial acceleration of a driving axle was used in the above example.

[0041]

[Effect of the Invention] As explained above, according to this invention, the adhesion coefficient at the time of racing / skid generating is presumed substantially. Since the amount of current (or torque) reduction for making it re-adhere using this estimate is controlled as much as possible and he is trying to generate the current (or torque) corresponding to a presumed adhesion coefficient promptly at the time of re-adhesion Without readjusting a control parameter, even when an adhesion coefficient changes broadly, the tangential force between a wheel and a rail can be maintained to the value near the adhesion coefficient at that time, and the possible readhesion control approach of a deployment of adhesion can be offered.

[Translation done.]

* NOTICES *

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- 1.This document has been translated by computer. So the translation may not reflect the original precisely.
- 2.*** shows the word which can not be translated.
- 3.In the drawings, any words are not translated.

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]

[Drawing 1] It is the block diagram of the example of this invention according to claim 1.

[Drawing 2] It is the explanatory view of the example of this invention according to claim 1 of operation.

[Drawing 3] It is the explanatory view of the change situation of the tangential force between the torque or the torque command value change corresponding to the current command value by the example of this invention according to claim 1, and a wheel and a rail.

[Drawing 4] It is the block diagram of the example of this invention according to claim 2.

[Drawing 5] It is the explanatory view of the example of this invention according to claim 2 of operation.

[Drawing 6] It is the explanatory view of the change situation of the tangential force between the torque or the torque command value change corresponding to the current command value by the example of this invention according to claim 2, and a wheel and a rail.

[Drawing 7] It is the block diagram of the example of this invention according to claim 3.

[Drawing 8] It is drawing explaining actuation of the example of this invention according to claim 3.

[Drawing 9] It is the explanatory view of the change situation of the tangential force between the torque or the torque command value change corresponding to the current command value by the example of this invention according to claim 3, and a wheel and a rail.

[Drawing 10] It is drawing showing the example of the tangential-force property between the wheel and rail to sliding velocity.

[Description of Notations]

- 1 Racing / Skid Detection Section
- 2 Main Motor Current Control Section
- 3 Current Command Value Reduction Command Generating Section
- 4 Current Command Value Generating Section
- 5 Axial Acceleration Zero Detecting Element
- 6 Tangential-Force Presumption Section (A)
- 7 Delta μ Setting-Out Section
- 8 Current Command Value Desired Value Setting-Out Section
- 9 Re-Adhesion Detecting Element
- 10 Time Amount To — Counting — Section
- 11 Current Command Value Generating Section corresponding to Setting-Out Engine Performance of Car
- 12 Average Shaft Acceleration Operation Part
- 13 Axial Acceleration Minimum Value Detecting Element
- 14 Tangential-Force Presumption Section (B)
- 15 Tangential-Force Presumption Section (E)
- 16 Racing / Skid Detection Section (D)
- 17 Tangential-Force Presumption Section (F)
- 18 Axial Rate Operation Part
- 19 Axial Acceleration Operation Part

[Translation done.]

【特許請求の範囲】

【請求項1】 電気車の各動軸あるいは主電動機軸の軸速度と軸速度の時間微分値である軸加速度を計測または推定し、前記軸加速度の観測値（または推定値）が第一のしきい値を超えたことによって空転（あるいは滑走）を検出し、空転（あるいは滑走）を検出した後、主電動機電流の指令値すなわち電流指令値（またはトルク指令値） I_p を低減して空転（あるいは滑走）状態にある動軸の主電動機電流を減少させて再粘着に向かわせる電気車制御装置において、前記動軸の空転を空転・滑走検知部1にて検出した後、主電動機電流制御部2への電流指令値（またはトルク指令値） I_p を電流指令値低減指令発生部3からの指令を受けて電流指令値発生部4にて低減し、軸加速度がゼロになるときを軸加速度ゼロ検出部5で検出し、前記電流指令値（またはトルク指令値） I_p あるいは主電動機電流の前記観測値を接線力推定部

(A)6において前記動軸の空転（あるいは滑走）開始時の車輪・レール間の接線力の第一の推定値に対応した電流指令値（またはトルク指令値） I_{pa1} と見なし、前記接線力の第一の推定値に対応した電流指令値（またはトルク指令値） I_{pa1} より少ない電流指令値 δI_{pa} を電流指令値目標設定部（ δI_{pa} 設定部）7にて設定し、この値だけ下回る電流指令値（またはトルク指令値） $I_{pa1} - \delta I_{pa}$ を電流指令値目標設定部8で低減の目標値としてこの目標値に向かって電流指令値

（またはトルク指令値）を低減し、前記空転（または滑走）軸を再粘着に向かわせるとともに、前記空転（または滑走）軸の軸加速度がマイナス側からプラス側に転じて（あるいは滑走の場合はプラス側からマイナス側に転じて）再粘着したか否かを再粘着検出部9にて検出し、再粘着するときから、前記接線力の第一の推定値に対応した電流指令値 I_{pa1} を、時間 T_o 計数部10において任意に定めうる時間 T_o を計数するまで電流指令値発生部4において継続して指令し、前記時間 T_o 経過後から、車両の設定性能に対応した電流指令値発生部11の値を目標値として電流指令値発生部4で電流指令値（またはトルク指令値）を任意に定めうる増大率で増大させるよう制御することを特徴とする電気車の再粘着制御方法。

【請求項2】 前記動軸の空転を空転・滑走検知部1にて検出した後、前記主電動機電流制御部2への電流指令値（またはトルク指令値） I_p を電流指令値低減指令発生部3からの指令を受けて電流指令値発生部4にて低減し、軸加速度がゼロになるときを軸加速度ゼロ検出部5で検出し、前記電流指令値（またはトルク指令値） I_p あるいは主電動機電流の前記観測値を接線力推定部

(A)6において前記動軸の空転（あるいは滑走）開始時の車輪・レール間の接線力の第一の推定値に対応した電流指令値（またはトルク指令値） I_{pa1} と見なし、前記接線力の第一の推定値に対応した電流指令値（また

はトルク指令値） I_{pa1} より少ない電流指令値 δI_{pa} を δI_{pa} 設定部7にて設定し、この値だけ下回る電流指令値（またはトルク指令値） $I_{pa1} - \delta I_{pa}$ を電流指令値目標設定部8で低減の目標値としてこの目標値に向かって電流指令値（またはトルク指令値）を低減していき、前記 $I_{pa1} - \delta I_{pa}$ に電流指令値（またはトルク指令値）が到達した直後から、任意に定めうる一定の期間中における前記空転軸の軸加速度の平均値 α_{avm} を平均軸加速度演算部12で演算し、前記電流指令値（またはトルク指令値） $I_{pa1} - \delta I_{pa}$ を指令中における前記空転軸の軸加速度が最小値すなわちマイナスの値でその絶対値が最大の α_{min} となったことを軸加速度最小値検出部13で検出し、前記 α_{min} と前記電流指令値 I_{pa1} と前記 δI_{pa} とから $I_{pa1} + \{(\alpha_{min}/\alpha_{avm}) - 1\} \cdot \delta I_{pa}$ によって接線力の第二の推定値に対応した電流指令値（またはトルク指令値） I_{pa2} を接線力推定部(B)14において演算し、前記空転軸の軸加速度がマイナス側からプラス側に転じて（あるいは滑走の場合はプラス側からマイナス側に転じて）再粘着したか否かを再粘着検出部9にて検出し、再粘着するときから、前記接線力の第二の推定値に対応した電流指令値（またはトルク指令値） I_{pa2} を時間 T_o 計数部10において任意に定めうる時間 T_o を計数するまで電流指令値発生部4で継続して指令し、前記時間 T_o 経過後から、車両の設定性能に対応した電流指令値発生部11の値を目標値として電流指令値発生部4で電流指令値（またはトルク指令値）を任意に定めうる増大率で増大させることを特徴とする電気車の再粘着制御方法。

【請求項3】 前記動軸の空転を空転・滑走検知部1にて検出した後、前記空転軸が再粘着するときに、請求項1に記載の前記接線力の第一の推定値に対応した電流指令値（またはトルク指令値） I_{pa1} 、または請求項2に記載の前記接線力の第二の推定値に対応した電流指令値（またはトルク指令値） I_{pa2} を時間 T_o 計数部10において前記任意に定めうる時間 T_o を計数するまで電流指令値発生部4において継続して指令し続けた後に電流指令値（またはトルク指令値）を任意に定めうる電流指令値（またはトルク指令値）の単位時間当たりの増加率 ΔI_p に従って増大させ、前記電流指令値（またはトルク指令値）を増大させ始めた時点からの時々刻々の電流指令値（またはトルク指令値）または主電動機電流の観測値 $I_p(t)$ と前記動軸の軸加速度 $\alpha(t)$ を接線力推定部(E)15において記憶しておき、空転・滑走検出部(D)16において前記再粘着軸の軸加速度が前記電流指令値の増加率 ΔI_p に対応した増加率で増大し始めることを検出することによって再空転（あるいは再滑走）を検知し、前記動軸の再空転（あるいは再滑走）検出をした時点から遡って接線力推定部(E)15において前記軸加速度の記憶値 $\alpha(t)$ を順次調べて最

初に前記増加率 ΔI_p に対応した軸加速度的増加が発生した時点における電流指令値（あるいはトルク指令値）あるいは主電動機電流の前記観測値の記憶値 $I_p(t)$ を接線力の第三の推定値に対応した電流指令値（あるいはトルク指令値） I_{pa3} とし、前記接線力の第三の推定値に対応した電流指令値（またはトルク指令値） I_{pa3} から δI_{pa} 設定部7で設定した前記 δI_{pa} 下回る電流指令値（またはトルク指令値） $I_{pa3} - \delta I_{pa}$ を電流指令値（またはトルク指令値）の目標値としてこの目標値に向かって電流指令値（またはトルク指令値） I_p を低減し、軸加速度がゼロになるときを軸加速度ゼロ検出部5で検出し、この時点における電流指令値（あるいはトルク指令値）を I_{pa3d} として $I_{pa3d} - \delta I_{pa}$ に電流（あるいはトルク）低減の目標値を電流指令値目標値設定部8において修正し、平均軸加速度演算部12において前記の修正した電流（あるいはトルク）低減の目標値 $I_{pa3d} - \delta I_{pa}$ に前記主電動機電流制御部2への電流指令値（またはトルク指令値）が到達した直後から任意に定めうる期間中における前記空転軸の軸加速度の平均値 α_{avm1} を演算し、軸加速度最小値検出部13において前記の修正した電流（またはトルク）低減の目標値 $I_{pa3d} - \delta I_{pa}$ を継続して指令中における前記空転軸の軸加速度が最小値すなわちマイナスの値でその絶対値が最大の α_{min1} となったことを検出した時点において、前記 α_{min1} と前記 I_{pa3d} と前記 δI_{pa} とから $I_{pa3d} + \{(\alpha_{min1} / \alpha_{avm1}) - 1\} \cdot \delta I_{pa}$ によって接線力の第四の推定値に対応した電流指令値（またはトルク指令値） I_{pa4} を接線力推定部(F)17において演算し、前記空転軸の軸加速度がマイナス側からプラス側に転じて（あるいは滑走の場合はプラス側からマイナス側に転じて）再粘着したか否かを再粘着検出部9にて検出し、再粘着するときから、前記接線力の第三の推定値に対応した電流指令値（またはトルク指令値） I_{pa3} と前記接線力の第四の推定値に対応した電流指令値（またはトルク指令値） I_{pa4} のうちの小さい方の推定値に対応した電流指令値（またはトルク指令値）を電流指令値目標値設定部8で設定して前記任意に定めうる時間 T_o を時間 T_o 計数部10で計数するまで継続して指令し、前記時間 T_o 経過後から、車両の設定性能に対応した電流指令値発生部11で設定した電流指令値（またはトルク指令値）を目標値として電流指令値発生部4において電流指令値（またはトルク指令値）を任意に定めうる増大率で増大させることを特徴とする電気車の再粘着制御方法。

【発明の詳細な説明】

【0001】

【発明が属する技術分野】本発明は、電気車の主電動機を駆動制御する電気車制御装置の再粘着制御方法で、特に粘着力の有効利用を図った電気車の再粘着制御方法に

関する。

【0002】

【従来の技術】電気車は車輪・レール間の接線力（粘着力ともいう）によって加減速を行っているが、この接線力は、一般にすべり速度に対して図10に破線で示すような特性を有している。この接線力の最大値を軸重（車輪1軸当たりのレールに加わる垂直荷重）で割ったものを粘着係数、それ以外の接線力を軸重で割ったものを含めて接線力係数という。図示の如く、接線力の最大値を超えないトルクを主電動機で発生している場合は、空転・滑走は発生せず、接線力の最大値より左側の破線で示す微小なすべり速度で電気車は走行する。もし最大値より大きいトルクを発生するとすべり速度は増大し、接線力が低下するのでますますすべり速度が増大する空転・滑走状態になるが、車輪及びレールが乾燥状態では主電動機で発生するトルクは接線力の最大値を超えないように車両の性能が設定されるので、空転・滑走は発生しない。

【0003】しかし、実線で示す如く、レール面が雨等によって湿潤状態にある場合は、粘着係数が低下して接線力の最大値が車両の設定性能に対応した主電動機の発生トルクより小さくなる。この場合、すべり速度が増大し空転状態になり、そのまま放置するとこれに対応して接線力が低下し、車両の加速に必要な加速力がますます低下してしまうので、迅速に空転・滑走を検出し、主電動機が発生するトルクを低減して再粘着させることが必要になる。このようにトルクの制御を行って再粘着させる場合、小さなすべり速度に抑制しつつ、主電動機の発生トルクが極力接線力の最大値近傍の値になるように制御することが、電気車の加減速性能を高める上で必要である。

【0004】このような再粘着制御の実現を目的とした方法として、主電動機の回転周波数（回転速度）を検出し、これからその時間変化率、すなわち加速度を求めて空転・滑走を検出するとともに、空転・滑走検出時の主電動機軸の軸加速度に対応した時定数で主電動機の電流パターンを低減して再粘着を図り、空転軸が再粘着に向かい始めるとそのときの軸加速度に対応した時定数でトルクを復帰させる方法がある。

【0005】また別の方法として、空転発生時に動軸加速度からそのときの主電動機トルクに対応した粘着係数からの低下分を推定することによって粘着係数を推定し、再粘着後に推定した粘着係数に対応したトルクを主電動機で発生するようにした再粘着制御方法がある。

【0006】

【発明が解決しようとする課題】しかしながら、前者の方法では、トルクの低減・増大の時定数を空転検出時および再粘着に向かうときの状況に応じて設定しているので、実際の粘着係数の変化にある程度は対応してトルク制御ができることから粘着力の有効利用が図れる場合が

ある。しかし粘着係数に対応した接線力を推定している訳ではないので、粘着係数がどのように変化した場合でも正しく適応して制御できる保証はなく、電気車の投入線区、気象条件等によって粘着係数が広範囲に変化した場合には制御パラメータの再設定をしないとすべり速度が大きくなって、粘着力の有効利用が図れない場合が発生する。また後者の方法の場合、動軸の軸加速度と動軸の慣性モーメントの積から粘着係数の低下分を推定しているもので、動軸の車輪径が小さくなった場合に動軸周上でみた動軸まわりの慣性モーメントが変わるので、これ

に対応して粘着係数の推定誤差が発生するという問題点がある。

【0007】本発明は上述した点に鑑みて創案されたもので、その目的とするところは、これらの欠点を解決することにあり、粘着係数が広範囲に変化しても、空転・滑走検出時の車輪・レール間の粘着係数を常に精度良く推定し、制御パラメータの調整を必要としない粘着力の有効利用が可能な電気車の再粘着制御方法を提供することにある。

【0008】

【課題を解決するための手段】つまり、その目的を達成するための手段は、

1) 請求項1において、車両の設定性能に対応した電流指令値(またはトルク指令値)を指令している時に空転または滑走を検出した場合に空転または滑走検出後、主電動機電流の電流指令値(あるいはトルク指令値)を低減して空転軸を再粘着に向かわせる過程で、空転軸の軸加速度がゼロになった時点すなわち空転軸の空転速度が減少に転ずる時点における電流指令値(あるいはトルク指令値)あるいは電流の観測値を接線力の推定値に対応した電流指令値(あるいはトルク指令値) I_{pa1} と見なし(第一の接線力推定方法)、この第一の接線力推定方法によって推定した接線力の推定値に対応した電流指令値(あるいはトルク指令値) I_{pa1} より僅かに δI_{pa} だけ下回る $I_{pa1} - \delta I_{pa}$ まで主電動機電流の電流指令値(あるいはトルク指令値)を低減し、電流指令値(あるいはトルク指令値)が $I_{pa1} - \delta I_{pa}$ に達した後はこの $I_{pa1} - \delta I_{pa}$ を指令し続けて、軸加速度がマイナス側からプラス側に転じて(滑走の場合はプラス側からマイナス側に転じて)再粘着した時点から任意に定めうる期間 T_o の間、第一の接線力推定方法によって推定した接線力の推定値に対応した電流指令値(あるいはトルク指令値) I_{pa1} を指令し続け、その後電流指令値(あるいはトルク指令値)を車両の設定性能に対応した電流指令値(あるいはトルク指令値)へ向けて増大させる方法を備えることによってなされる。

【0009】2) 請求項2においては、車両の設定性能に対応した電流指令値(またはトルク指令値)を指令している時に空転または滑走を検出した場合に、空転または滑走検出後主電動機電流の電流指令値(あるいはトル

ク指令値)を低減して空転軸を再粘着に向かわせる過程で、前記第一の接線力推定方法によって、空転軸の軸加速度がゼロになった時点における電流指令値(あるいはトルク指令値)あるいは電流の観測値を接線力の推定値に対応した電流指令値(あるいはトルク指令値) I_{pa1} と見なし、この I_{pa1} より僅かに δI_{pa} だけ下回る $I_{pa1} - \delta I_{pa}$ まで主電動機の電流指令値(あるいはトルク指令値)を低減し、電流指令値(あるいはトルク指令値)が $I_{pa1} - \delta I_{pa}$ に達した後はこの $I_{pa1} - \delta I_{pa}$ を指令し続け、 $I_{pa1} - \delta I_{pa}$ に達した直後の任意に定めうる期間中における平均軸加速度 α_{avm} を求め、その後 $I_{pa1} - \delta I_{pa}$ を指令中における空転軸の軸加速度の最小値 α_{min} とから、 $I_{pa1} + [(\alpha_{min} / \alpha_{avm}) - 1] \cdot \delta I_{pa}$ によって求めた修正電流指令値(あるいはトルク指令値)を接線力の最大値(すなわち粘着係数に対応した接線力)の推定値に対応した電流指令値(あるいはトルク指令値) I_{pa2} と見なし(第二の接線力推定方法)、軸加速度がマイナス側からプラス側に転じて(滑走の場合はプラス側からマイナス側に転じて)再粘着した時点から任意に定めうる期間 T_o の間、第二の接線力推定方法によって求めた接線力の最大値に対応した電流指令値(あるいはトルク指令値) I_{pa2} を指令し続け、その後電流指令値(あるいはトルク指令値)を車両の設定性能に対応した電流指令値(あるいはトルク指令値)に向けて増大させる方法を備えるようにしたものである。

【0010】3) 請求項3においては、第一の接線力推定方法によって推定した接線力の推定値に対応した電流指令値(あるいはトルク指令値) I_{pa1} あるいは第二の接線力推定方法によって推定した接線力の推定値に対応した電流指令値(あるいはトルク指令値) I_{pa2} を、軸加速度がマイナス側からプラス側に転じて(滑走の場合はプラス側からマイナス側に転じて)再粘着した時点から任意に定めうる期間 T_o の間指令し続けた後、電流指令値(あるいはトルク指令値)をある増加率で増大させて行き、電流指令値(あるいはトルク指令値)を増加させ始めた時点以降、時々刻々の電流指令値(あるいはトルク指令値)あるいは主電動機電流の観測値と軸加速度を保持しておき、この電流指令値(あるいはトルク指令値)増大過程で電流指令値(あるいはトルク指令値)の増加率に対応した増加率で軸加速度の増加が観測された時点で再空転の検出を行うことを第二の空転検出方法とし、第二の空転検出方法によって再空転を検出した時点より遡って最初に軸加速度の増加が始まったときの電流指令値(あるいはトルク指令値)あるいは主電動機電流の観測値 $I_p(t)$ を接線力の推定値に対応した電流指令値(あるいはトルク指令値) I_{pa3} とし(第三の接線力推定方法)、第三の推定方法によって推定した接線力の推定値に対応した電流指令値(あるいはトルク指令値) I_{pa3} より僅かに δI_{pa} だけ下回る I_{pa}

3- δIpa を目標値として主電動機への電流指令値（あるいはトルク指令値）を低減し、軸加速度がゼロになった時点における電流指令値（あるいはトルク指令値）を $Ipa3d$ として $Ipa3d-\delta Ipa$ に電流（あるいはトルク）低減の目標値を修正し、電流が電流指令値（あるいはトルク指令値）の目標値 $Ipa3d-\delta Ipa$ に達した直後の任意に定めうる期間中における平均軸加速度 $\alpha avm1$ を求め、その後 $Ipa3d-\delta Ipa$ を指令中における空転軸の軸加速度の最小値 $\alpha min1$ とから、 $Ipa3d+[(\alpha min1/\alpha avm1)-1]\cdot\delta Ipa$ によって求めた修正電流指令値（あるいはトルク指令値）を接線力の推定値に対応した電流指令値（あるいはトルク指令値） $Ipa4$ とし（第四の接線力推定方法）、空転が収まって再粘着した時点で、第三と第四の接線力推定方法で推定した接線力の推定値に対応した電流指令値（あるいはトルク指令値） $Ipa3$ と $Ipa4$ のうちの小さいほうの電流指令値（あるいはトルク指令値）を前記期間 To の間指令するようにし、その期間が過ぎた後、ある増加率で車両の設定性能に対応した電流指令値（あるいはトルク指令値）に向けて電流指令値（あるいはトルク指令値）を増大させる方法を備えるようにしたものである。

【0011】

【発明の実施の形態】以下、本発明による電気車の再粘着制御方法について、図示の実施例を用いて詳細に説明する。図1は本発明の請求項1に記載の実施例を示すブロック図、図2は本発明の請求項1に記載の実施例の動作説明図、図3は図1の実施例による電流指令値に対応したトルクあるいはトルク指令値の変化と車輪・レール間の接線力の変化状況の説明図である。なお以下においては空転の場合についてのみ説明する。滑走の場合は、軸速度、軸加速度の変化が空転の場合と逆になるだけでその他基本的には変わらないので省略する。図1～3において、図示しない主幹制御器からの運転指令 a が主電動機電流指令系（あるいはトルク指令系：以下においては電流指令系で代表させる） b に入力され、車両の設定性能に対応した電流指令値（あるいはトルク指令値：以下においては電流指令値で代表させる）を車両の設定性能に対応した電流指令値発生部11で発生し、電流指令値目標値設定部8に出力する。これにともなう、車両の設定性能に対応した電流指令値（あるいはトルク指令値）、すなわち接線力の推定値に対応した電流指令値より小さい電流指令値 δIpa を電流指令値目標値設定部7（ δIpa 設定部）で設定している。

【0012】一方、図示しない動軸あるいは主電動機軸に取り付けられた速度センサからの軸速度パルス c が軸速度演算部18に入力されて軸速度が演算され、演算された軸速度は軸加速度演算部19に入力されて、軸加速度が演算される。軸加速度は次いで空転・滑走検知部1に入力される。車輪・レール間の粘着係数がレール乾燥

時のように十分大きい場合には、軸加速度が空転・滑走検出のしきい値に達しないので、空転・滑走検知部1の出力である空転・滑走検知信号は出力されず、電流指令値低減指令発生部3では電流指令値低減信号を発生しないので、電流指令値発生部4において、電流指令値目標値設定部8で設定している車両の設定性能に対応した電流指令値を主電動機電流制御部2に指令し続けている（図2の時刻 $t0$ 以前の状態）。

【0013】次いで、降雨等によって粘着係数が小さくなって車輪・レール間の接線力が主電動機で発生しているトルクよりも小さくなると（図2の時刻 $t0$ ）、空転が発生して動軸が加速されて軸加速度がしきい値を超えるようになる（図2の時刻 $t1$ ）。この時点で図1の空転・滑走検出部1で空転を検出し、空転・滑走検知信号を出力する。電流指令値低減指令発生部3では、空転・滑走検知信号が入力されると、電流指令値低減信号を発生するので、電流指令値発生部4では電流指令値をある減少速度で減少させる。これによって空転軸の空転速度が減少し始める。したがって、軸加速度も減少し、やがては軸加速度ゼロ点を通してマイナス軸加速度になる。そこで、軸加速度演算部19からの軸加速度が入力されている軸加速度ゼロ検出部5では、空転・滑走検知信号が出力されたことを条件として、入力されている軸加速度を調べて軸加速度がゼロとなった時点（図2の時刻 $t11$ ）で、軸加速度ゼロ検出信号を接線力推定部（A）6に対して出力する。

【0014】接線力推定部（A）6では、軸加速度ゼロ検出信号を受信した時点の主電動機電流指令系から入力される電流指令値をその時の接線力の推定値と見なし、これを接線力の第一の推定値に対応した電流指令値 $Ipa1$ として出力する。そして、空転軸を確実に再粘着させるために、 δIpa 設定部7で設定した前述の δIpa を減算した $Ipa1-\delta Ipa$ を電流指令値低減の目標値として電流指令値目標値設定部8で設定する。この δIpa は空転軸を確実に再粘着させることができる範囲内で極力小さな値として、いたずらに電流指令値の低減量が大きくなることを回避する。

【0015】電流指令値発生部4では、この目標値 $Ipa1-\delta Ipa$ に電流指令値が達すると（図2の時刻 $t2$ ）、電流指令値をこの目標値 $Ipa1-\delta Ipa$ に維持し続ける。これによって空転軸が再粘着する。この時に軸加速度がマイナス側から再びゼロを通過してプラス側に転ずる。そこで、再粘着検出部9では軸加速度演算部19からの軸加速度を入力して、軸加速度がマイナス側からゼロを通過した時点（図2の時刻 $t3$ ）で、空転・滑走検知信号及び軸加速度ゼロ検出信号が出力されたことを条件として、再粘着検知信号を電流指令値目標値設定部8に対して出力する。電流指令値目標値設定部8ではこの再粘着検知信号を受信すると、先に接線力推定部（A）6が出力した接線力の推定値に対応した電流指

令値 I_{pa1} を目標値として設定するので、電流指令値発生部4では第一の推定値に対応した電流指令値 I_{pa1} に向かって電流指令値を、主電動機電流制御系の制御擾乱や台車のピッチング運動を誘発しない範囲内の極力大きな増大速度で増大させる。

【0016】そして、上記 I_{pa1} に電流指令値が達した時点（図2の時刻 t_{31} ）で、電流指令値上限値到達信号を時間 T_o 計数部10に対して出力するとともに、電流指令値を I_{pa1} に維持する。そして一定期間 T_o 経過すると（図2の時刻 t_4 ）、時間 T_o 計数部10は時間 T_o 経過信号を電流指令値目標値設定部8に対して出力する。これによって電流指令値目標値設定部8は、その時の車両の設定性能に対応した電流指令値を設定するので、電流指令値発生部4ではこの目標値に向かって、乗り心地を害しないような増大速度で電流指令値を増大させて制御を終了する。上記の期間 T_o の長さは任意に定めうる一定値である。 T_o はあまり長くするとその間に粘着係数が変化して、上記の I_{pa1} を指令したのでは実際値との間に乖離を生じてしまい、またあまり短くし過ぎると空転・再粘着が頻繁に繰り返されて再粘着させるための電流指令値の低減による影響（ δI_{pa} の影響）が大きくなり、電気車の加速に使用される接線力の損失が増大するので、これらの点を考慮して設定すればよい。

【0017】図3に示すように、空転検出性能が良好で空転速度が小さいうちに空転を検出できる場合には、軸加速度が最初にゼロになった時点（図2の時刻 t_{11} ）での電流指令値 I_{pa1} は、粘着係数に対応した接線力に非常に近い値である。そのため、以上のような制御を行うことによって、再粘着の過程では I_{pa1} より僅かに δI_{pa} だけ小さいトルクを指令し、再粘着後は粘着係数に対応した接線力に非常に近い値である I_{pa1} を指令することになり、粘着係数がどのように変化してもそのときの粘着係数に近い接線力に維持することができるので、粘着力の有効利用が図れることになる。

【0018】図4は本発明の請求項2に記載の実施例を示すブロック図、図5は本発明の請求項2の実施例の動作図、図6は図4の実施例による電流指令値に対応したトルクあるいはトルク指令値の変化と車輪・レール間の接線力の変化状況の説明図である。図4の実施例が図1の請求項1の実施例と異なるところは、主電動機電流指令系の電流指令値発生部4から電流指令値下限値到達信号が追加され、また平均軸加速度演算部12、軸加速度最小値検出部13、接線力推定部（B）14とそれらの出力である平均軸加速度 α_{avm} 、最小軸加速度 α_{min} 、接線力の第二の推定値に対応した電流指令値（またはトルク指令値） I_{pa2} の信号が追加されていることである。

*

$$I_{pa2} = I_{pa1} + [(\alpha_{min} / \alpha_{avm}) - 1] \cdot \delta I_{pa} \quad \cdots (1)$$

【0023】図6に示してあるように、 $I_{pa1} - \delta I_{pa}$ を指令して空転軸が再粘着に向かっている過程です

* 【0019】図4において、図1の場合と同じく、車両の設定性能に対応した電流指令値を指令して電気車が走行している時に粘着係数が急に低下して空転が始まり（図5の時刻 t_o ）、その後軸加速度が空転検知のしきい値以上になって空転を検出すると（図5の時刻 t_1 ）、この時点で空転・滑走検出部1で空転・滑走検知信号を出力し、主電動機電流指令系では、空転・滑走検知信号が入力されると、電流指令値をある減少速度で減少させ、空転・滑走検知信号が出力されたことを条件として、軸加速度ゼロ検出部5では入力されている軸加速度を調べて軸加速度がゼロとなった時点（図5の時刻 t_{11} ）で、軸加速度ゼロ検出信号を接線力推定部（A）6に対して出力する。

【0020】接線力推定部（A）6では、軸加速度ゼロ検出信号を受信した時点の主電動機電流指令系から入力される電流指令値をその時の接線力の推定値と見なし、これを接線力の推定値に対応した電流指令値 I_{pa1} として出力する。そして、空転軸を確実に再粘着させるために、 δI_{pa} 設定部7で設定した δI_{pa} を減算した $I_{pa1} - \delta I_{pa}$ を電流指令値低減の目標値として主電動機電流指令系に出力する。この δI_{pa} は空転軸を確実に再粘着させることができる範囲内で極力小さな値として、いたずらに電流指令値の低減量が大きくなることを回避する。主電動機電流指令系では、この目標値 $I_{pa1} - \delta I_{pa}$ に電流指令値が到達するまで、電流指令値を低減する。以上のところまでの制御は図1と同じである。

【0021】図4において、電流指令値が $I_{pa1} - \delta I_{pa}$ にまで減少した時点（図5の時刻 t_2 ）で、電流指令値発生部4において電流指令値下限値到達信号が平均軸加速度演算部12に対して出力される。そして電流指令値が $I_{pa1} - \delta I_{pa}$ に維持される。平均軸加速度演算部12では、電流指令値下限値到達信号を受信すると、任意に定めうる一定の期間中（図5の時刻 t_2 から t_{21} までの期間）に入力された軸加速度をもとにその平均値である平均軸加速度信号 α_{avm} を演算する。その後電流指令値が $I_{pa1} - \delta I_{pa}$ に維持され続けて空転軸が再粘着するときに軸加速度がマイナス側から再びゼロを通過してプラス側に転ずるが、この時点（図5の時刻 t_{31} ）までの間に、軸加速度最小値検出部13において最小軸加速度 α_{min} を検出する（図5の時刻 t_{22} において軸加速度が最小になる）。そして平均軸加速度 α_{avm} と最小軸加速度 α_{min} とから、接線力推定部（B）14において、接線力の第二の推定値に対応した電流指令値 I_{pa2} を(1)式によって演算する。

【0022】

べり速度が減少してくると車輪・レール間の接線力が増大してくる。そして、軸加速度が最小値 α_{min} になったとき (図5の時刻 t_{22})、 α_{min} はそのときの車輪・レール間の粘着係数に対応した接線力と電流指令値 $I_{pa1} - \delta I_{pa}$ に対応した接線力との差に相当する軸加速度になっている。したがって、(1) 式から求められる I_{pa2} は、そのときの粘着係数に対応した電流指令値になっている。ここで、空転軸の粘着係数を従来技術のように軸加速度を用いて (2) 式に従って推定する場合、(3) 式からもわかるように、動輪の車輪径が車輪の削正等によって小さくなると推定値の誤差が発生する。なお (2)、(3) 式で、 F_t は主電動機が発生する動輪周上引張力、 M_j は動輪周上でみた動軸・駆動系の慣性質量、 J は動軸まわりの慣性モーメント、 r は動輪の半径、 α は動軸加速度、 F_m は接線力である。

【0024】

$$F_m = F_t - M_j \cdot \alpha \quad \dots (2)$$

$$M_j = J / (r \cdot r) \quad \dots (3)$$

【0025】これに対して、(1) 式によって粘着係数に対応した電流指令値を求める場合、($\alpha_{min} / \alpha_{avm}$) を演算することによって慣性質量が変わる影響が除去されるので、動輪径が小さくなっても精度良く粘着係数を推定できることになる。再び図4において、接線力推定部 (B) 14 で推定した接線力の第二の推定値に対応した電流指令値 I_{pa2} が電流指令値目標値設定部 8 に対して出力され、またその後再粘着検出部 9 で再粘着検出信号が出力されると (図5の時刻 t_3)、接線力の第二の推定値に対応した電流指令値 I_{pa2} を電流指令値目標値設定部 8 で設定するので、電流指令値発生部 4 では I_{pa2} に向かって電流指令値を増大させる。そして、上記 I_{pa2} に電流指令値が達した時点 (図5の時刻 t_{22}) で電流指令値上限到達信号が時間 T_o 計数部 10 に対して出力されるので、図1の場合同様に、一定期間 T_o だけ I_{pa2} を指令し続け、 T_o が経過すると (図5の時刻 t_4)、そのときの車両の設定性能に対応した電流指令値に向かって電流指令値を増大させて制御を終了する。

【0026】図6に示すように、空転検出感度が低くて空転速度が大きくなって (したがって接線力がかなり低下してから) 空転検出して、図3に示す場合よりもトルク低減量が大きくなった場合でも、(2) 式によって再粘着直前の粘着係数に対応した接線力を精度良く推定できるので、再粘着時にそのときの粘着係数にほぼ対応した電流指令値を指令し、粘着力の有効利用可能な再粘着制御方法を提供できることになる。

【0027】図7は本発明の請求項3に記載の実施例を示すブロック図、図8は本発明の請求項3に記載の実施例の動作説明図、図9は図7の実施例による電流指令値に対応したトルクあるいはトルク指令値の変化と車輪・レール間の接線力の変化状況の説明図である。図7の請

求項3に記載の実施例が図4の請求項2の実施例と異なるところは、空転・滑走検出部 (D) 16、接線力推定部 (E) 15、接線力推定部 (F) 17および、これらの出力である再空転・滑走検知信号、接線力の第三の推定値に対応した電流指令値 (またはトルク指令値) I_{pa3} 、接線力の第四の推定値に対応した電流指令値 (またはトルク指令値) I_{pa4} 、軸加速度ゼロ検出時の電流指令値 I_{pa3d} が追加されていることである。

【0028】図7において、再粘着検出部9からの再粘着検知信号を主電動機電流指令系において受信すると、この時点 (図8の時刻 t_3) から前記の期間 T_o の間、電流指令値発生部4において、請求項1に記載の実施例で推定した第一の接線力の推定値に対応した電流指令値 I_{pa1} と請求項2に記載の実施例で推定した第二の接線力の推定値に対応した電流指令値 I_{pa2} のいずれかが継続して指令される。そして期間 T_o 経過した時点

(図8の時刻 t_4) から、電流指令値をそのときの車両速度から得られる車両の設定性能に対応した電流指令値を目標値として、例えば ΔI_p なる増加率で増大させる。このとき、時々刻々の動軸加速度 $\alpha(t)$ と電流指令値または主電動機電流の観測値 $I_p(t)$ が空転・滑走検知部 (D) 16および接線力推定部 (E) 15において記憶される。電流指令値が増大して主電動機の発生トルクが増大しても、動軸が粘着状態にあるときは、すべり速度は殆ど変化せず、軸加速度は車両の加速度に一致して推移する。

【0029】すなわち、図8の時刻 $t_3 \sim t_4$ 間の平均軸加速度 α_{av} にほぼ等しい値で推移する。その後、トルクの増大によって粘着状態から空転状態に移行すると、電流指令値の増加率 ΔI_p に対応した軸加速度の増大が制御周期毎に連続して観測されるようになる。そこで、図7の空転・滑走検知部 (D) 16において、この軸加速度の増大が連続して観測されるようになった時点 (図8の時刻 t_{41}) で再空転を検出し、再空転・滑走検知信号を出力する。このように電流指令値の増大過程において軸加速度の増大によって空転を検出すると、微小な空転速度のうちに空転を検出することができる。

【0030】次にこの再空転・滑走検知信号が出力されると、接線力推定部 (E) 15ではこの時点より過去に遡って軸加速度の記憶値 $\alpha(t)$ を順次調べて、最初に上記の増加率 ΔI_p に対応した軸加速度の増加が発生した時点における電流指令値または主電動機電流の観測値の記憶値 $I_p(t)$ を、空転発生時の接線力の第三の推定値に対応した電流指令値 I_{pa3} として出力する。なお上記の方法で電流指令値を増大させていっても再空転を検知せず、車両の設定性能に対応した電流指令値に達した場合には、その時点で再粘着制御は終了する。

【0031】接線力の第三の推定値に対応した電流指令値 I_{pa3} が出力されると、 I_{pa3} から δI_{pa} 設定

部6の設定値 δIpa だけ減算した $Ipa3 - \delta Ipa$ を電流指令値目標値設定部8において設定するので、電流指令値発生部4では $Ipa3 - \delta Ipa$ を目標値として、電流指令値を低減させる。そして、接線力推定部

(F)17において軸加速度ゼロ検出部5からの軸加速度ゼロ検出信号を受信した時点(図8の時刻 $t51$)における電流指令値 $Ipa3d$ を出力する。 $Ipa3d$ が出力されると、電流指令値目標値設定部8では δIpa 設定部の設定値 δIpa だけ減算した $Ipa3d - \delta Ipa$ に電流低減の目標値を修正するので、電流指令値発生部4では電流指令値を上記修正目標値 $Ipa3d - \delta Ipa$ にまで低減し続ける。そして、電流指令値が $Ipa3d - \delta Ipa$ まで減少した時点(図8の時刻 $t61$)で、請求項2に記載の実施例と同じく電流指令値発生部4において電流指令値下限値到達信号が平均軸加速度演算部12に対して出力される。そして電流指令値が $Ipa3d - \delta Ipa$ に維持される。 *

$$Ipa4 = Ipa3d + \{ (\alpha_{min1} / \alpha_{avm1}) - 1 \} \cdot (\delta Ipa)$$

..... (4)

【0034】再空転軸が再粘着して軸加速度がマイナス側から再びゼロを通過すると再粘着検出部9で再粘着検知信号が出力される(図8の時刻 $t7$)。この時点で電流指令値目標値設定部8では、接線力の第三の推定値に対応した電流指令値 $Ipa3$ と接線力の第四の推定値に対応した電流指令値 $Ipa4$ のうちの小さい方の電流指令値を目標値として設定するので、この目標値に向かって電流指令値発生部4において電流指令値を増大させる。そして、上記の小さい方の電流指令値に電流指令値が達した時点(図8の時刻 $t71$)から、一定期間 To だけ小さい方の電流指令値を指令し続ける。 To が経過すると図8の時刻 $t4$ の時点同様に、電流指令値をそのときの車両速度から得られる車両の設定性能に対応した電流指令値を目標値として、例えば ΔIpa なる増加率で増大させる。車両の設定性能に対応した電流指令値まで電流を増大させても、図7の空転・滑走検知部D16が再空転を検出しなければ、そこで再粘着制御は終了する。もし再空転を検出すれば、図8の時刻 $t4$ 以降の動作を繰り返す。

【0035】以上のように接線力の第三の推定値に対応した電流指令値 $Ipa3$ と接線力の第四の推定値に対応した電流指令値 $Ipa4$ のうちの小さい方の電流指令値を目標値として選択するのは、 $Ipa3$ のみを指令するようにすると、再空転検出時の実際の接線力に対応した電流指令値が、電流指令値を増大させる前に期間 To だけ指令していた電流指令値 $Ipa3$ より小さい場合に

(再空転検出時に再空転開始時の接線力の推定値に対応した電流指令値を求めても $Ipa3$ 以下にはならないので)、空転が徐々に拡大する事態となる可能性があるのをこれを防止するためである。上記のように $Ipa3$ と $Ipa4$ の小さい方を指令することによって、列車速度

*【0032】平均軸加速度演算部12では、電流指令値下限値到達信号を受信すると、任意に定めうる一定の期間中(図8の時刻 $t6$ から $t61$ までの期間)に入力された軸加速度をもとにその平均値である平均軸加速度信号 α_{avm1} を演算する。その後電流指令値が $Ipa3d - \delta Ipa$ に維持され続けて空転軸が再粘着するときには軸加速度がマイナス側から再びゼロを通過してプラス側に転ずるが、この時点(図8の時刻 $t7$)までの間に、軸加速度最小値検出部13において最小軸加速度 α_{min1} を検出する(図8の時刻 $t62$ において軸加速度が最小になる)。そして、平均軸加速度 α_{avm1} と最小軸加速度 α_{min1} とから、接線力推定部(F)17において、接線力の第四の推定値に対応した電流指令値 $Ipa4$ を、(4)式によって演算し、主電動機電流指令系に対して出力する。

【0033】

の上昇に伴って粘着係数が低下するという降雨時等に一般的に観測される状態にも、空転が徐々に拡大することなく常時推定粘着係数に対応した電流指令値を指令して車両を加速させることができる。

【0036】図9に請求項3に記載の実施例によって電流指令値を制御した場合のトルクあるいはトルク指令値の変化(太い実線で示す)と、車輪・レール間の接線力の変化状況を示すが、先にも述べたように、電流指令値の増大過程において電流指令値の増大量に対応した軸加速度の増大によって再空転を検出するので、微小な空転速度のうちに空転を検出することができ、したがって、より粘着力の有効利用が可能となる。

【0037】以上の本発明の再粘着制御方法を要約すると、以下のとおりである。

(1)請求項1に記載の実施例では、車両の設定性能に対応した電流指令値を指令しているときに空転・滑走を検出した場合で空転・滑走検出感度が高くて小さい空転速度のうちに空転・滑走を検出できる場合には、電流指令値を低減しつつ動軸加速度がゼロになるときの電流指令値を空転・滑走検出時の接線力の推定値 $Ipa1$ と見なし、電流指令値を $Ipa1 - \delta Ipa$ まで低減して再粘着に向かわせ、再粘着後速やかに $Ipa1$ をある一定期間指令し続け、一定期間経過後、そのときの車両の設定性能に対応した電流指令値に向けてある増加率で電流指令値を増大する制御を行う。

【0038】(2)請求項2に記載の実施例では、車両の設定性能に対応した電流指令値を指令しているときに空転・滑走を検出した場合で空転・滑走検出感度が低くて大きい空転速度のうちに空転・滑走を検出した場合には、電流指令値を低減しつつ動軸加速度がゼロになるときの電流指令値を空転・滑走検出時の接線力の推定値 I

p a 1と見なし、電流指令値を $I p a 1 - \delta I p a$ まで低減して再粘着に向かわせ、再粘着直前の接線力すなわち粘着係数に対応した接線力の推定値に対応した電流指令値 $I p a 2$ をある一定期間指令し続け、一定期間経過後、そのときの車両の設定性能に対応した電流指令値に向けてある増加率で電流指令値を増大する制御を行う。

【0039】(3) 一方、請求項3に記載の実施例では、そのときの設定性能に対応した電流指令値に向けてある増加率で電流指令値を増大している過程で空転・滑走を検出した場合(すなわち再空転・滑走を検出した場合)は、動軸の軸加速度が電流指令値の増加率に対応した増加率で増大し続けるようになる最初の時点における電流指令値を、再空転・滑走開始時の接線力の推定値に対応した電流指令値 $I p a 3$ と見なし、電流指令値を $I p a 3 - \delta I p a$ を目標値として低減し、途中で軸加速度がゼロになった時点でそのときの電流指令値 $I p a 3 d$ を用いて電流指令値低減の目標値を $I p a 3 d - \delta I p a$ に修正し、電流指令値を $I p a 3 d - \delta I p a$ まで低減して再粘着させるようにし、再粘着直前における接線力(すなわち粘着係数に対応した接線力)に対応した電流指令値 $I p a 4$ と上記 $I p a 3$ の小さい方の電流指令値を再粘着後ある一定期間指令し続け、一定期間経過後、そのときの車両の設定性能に対応した電流指令値に向けてある増加率で電流指令値を増大する制御を行う。

【0040】以上の実施例においては、空転・滑走検出時の接線力の推定値に対応する電流指令値と見なす $I p a 1 \sim I p a 4$ として、そのときの電流指令値を用いたが、これをその時の電流の観測値を用いるようにしてもよい。また、以上の実施例では、動軸の軸加速度としては、軸速度の観測値をもとに演算して求められる軸加速度を用いたが、誘導電動機を主電動機として用いたインバータ車両のように、主電動機の電圧・電流から動軸速度を推定することができる場合には、この推定軸速度をもとに演算した軸加速度を用いるようにしてもよい。

【0041】

【発明の効果】以上に説明したように本発明によれば、常に空転・滑走発生時の粘着係数を実質的に推定し、この推定値を用いて再粘着させるための電流(あるいはトルク)低減量を極力抑制するようにし、再粘着時に速やかに推定粘着係数に対応した電流(あるいはトルク)を発生させるようにしているので、粘着係数が広範囲に変化した場合でも、制御パラメータを再調整することなく、車輪・レール間の接線力をそのときの粘着係数に近い値に維持することができ、粘着力の有効利用の可能な再粘着制御方法を提供することができる。

【図面の簡単な説明】

【図1】本発明の請求項1に記載の実施例のブロック図である。

【図2】本発明の請求項1に記載の実施例の動作説明図である。

【図3】本発明の請求項1に記載の実施例による電流指令値に対応したトルクあるいはトルク指令値の変化と車輪・レール間の接線力の変化状況の説明図である。

【図4】本発明の請求項2に記載の実施例のブロック図である。

【図5】本発明の請求項2に記載の実施例の動作説明図である。

【図6】本発明の請求項2に記載の実施例による電流指令値に対応したトルクあるいはトルク指令値の変化と車輪・レール間の接線力の変化状況の説明図である。

【図7】本発明の請求項3に記載の実施例のブロック図である。

【図8】本発明の請求項3に記載の実施例の動作を説明する図である。

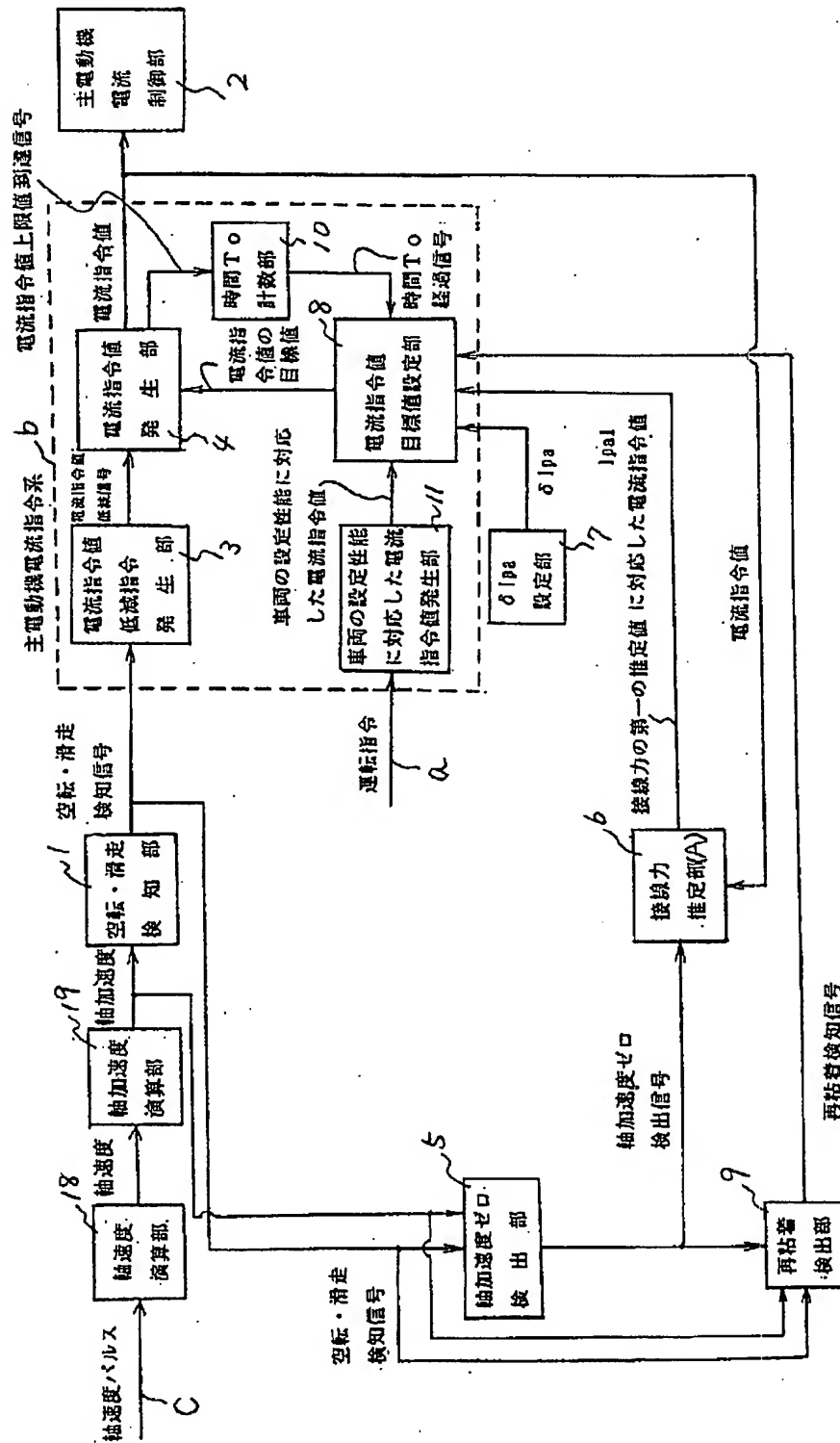
【図9】本発明の請求項3に記載の実施例による電流指令値に対応したトルクあるいはトルク指令値の変化と車輪・レール間の接線力の変化状況の説明図である。

【図10】すべり速度に対する車輪・レール間の接線力特性の例を示す図である。

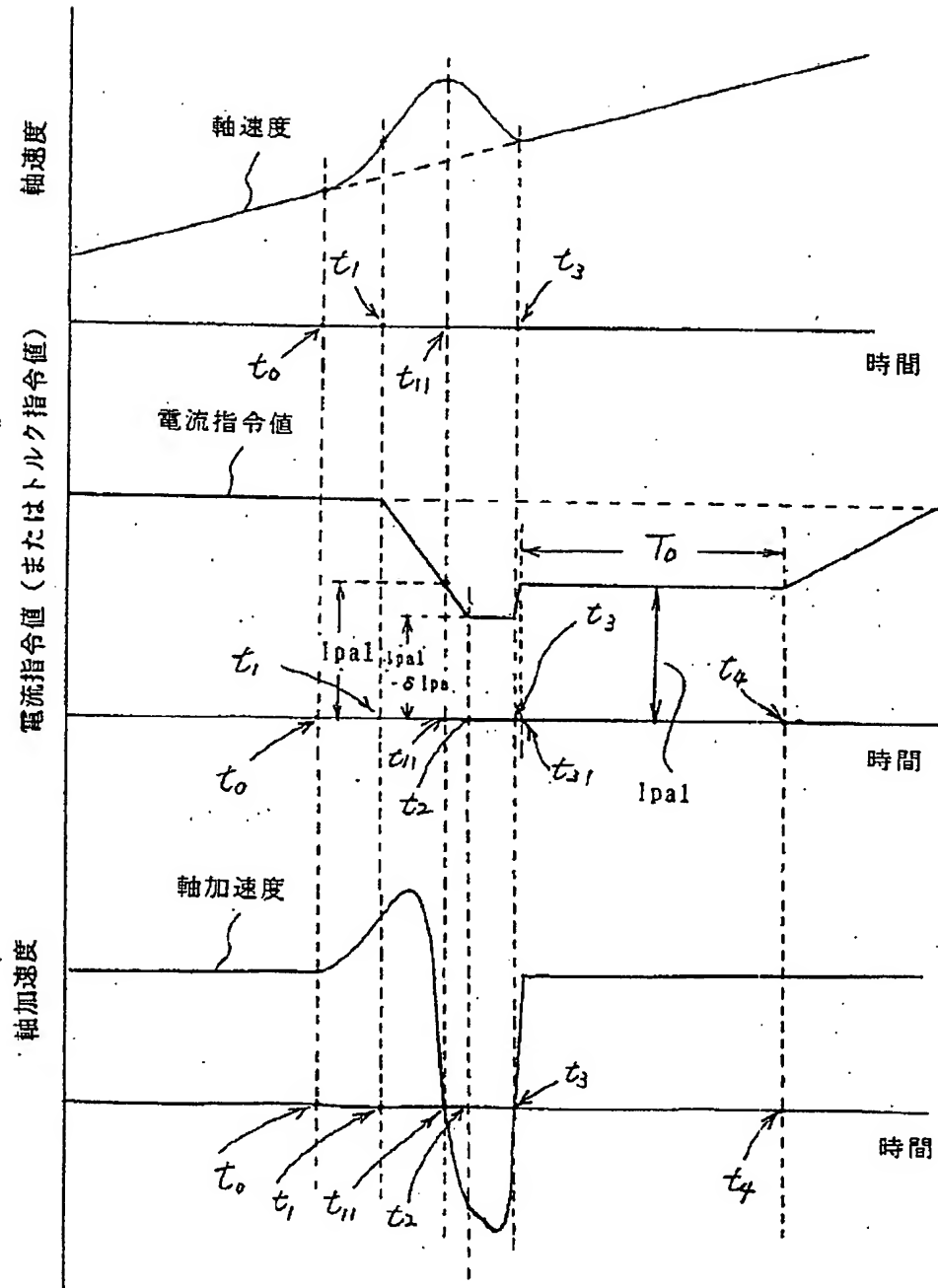
【符号の説明】

- 1 空転・滑走検知部
- 2 主電動機電流制御部
- 3 電流指令値低減指令発生部
- 4 電流指令値発生部
- 5 軸加速度ゼロ検出部
- 6 接線力推定部(A)
- 7 $\delta I p a$ 設定部
- 8 電流指令値目標値設定部
- 9 再粘着検出部
- 10 時間 $T o$ 計数部
- 11 車両の設定性能に対応した電流指令値発生部
- 12 平均軸加速度演算部
- 13 軸加速度最小値検出部
- 14 接線力推定部(B)
- 15 接線力推定部(E)
- 16 空転・滑走検知部(D)
- 17 接線力推定部(F)
- 18 軸速度演算部
- 19 軸加速度演算部

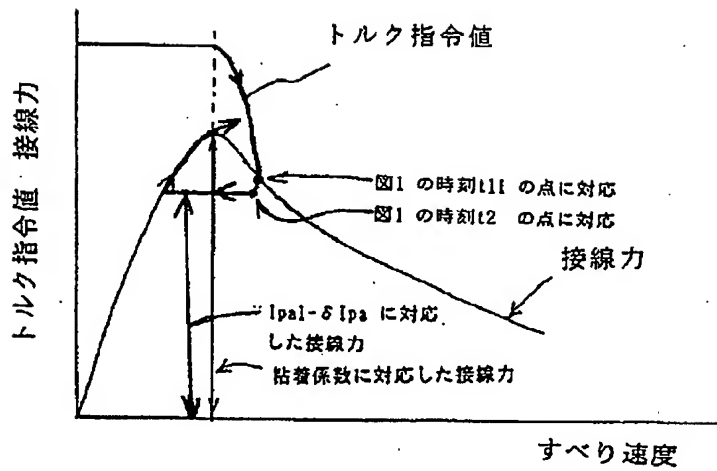
【図1】



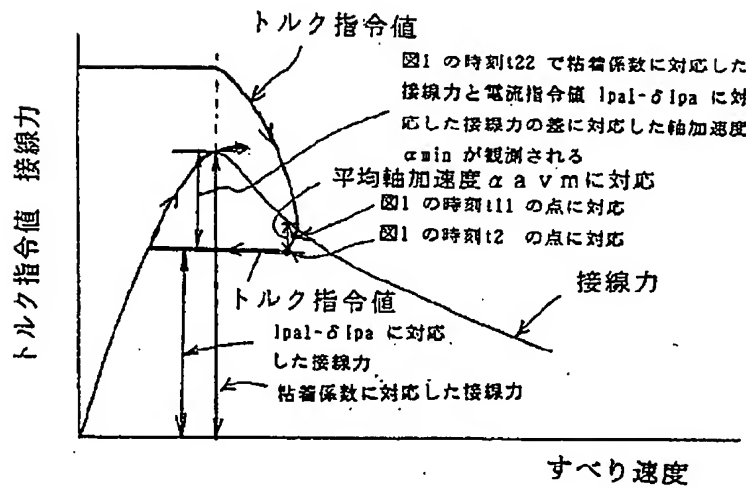
【図2】



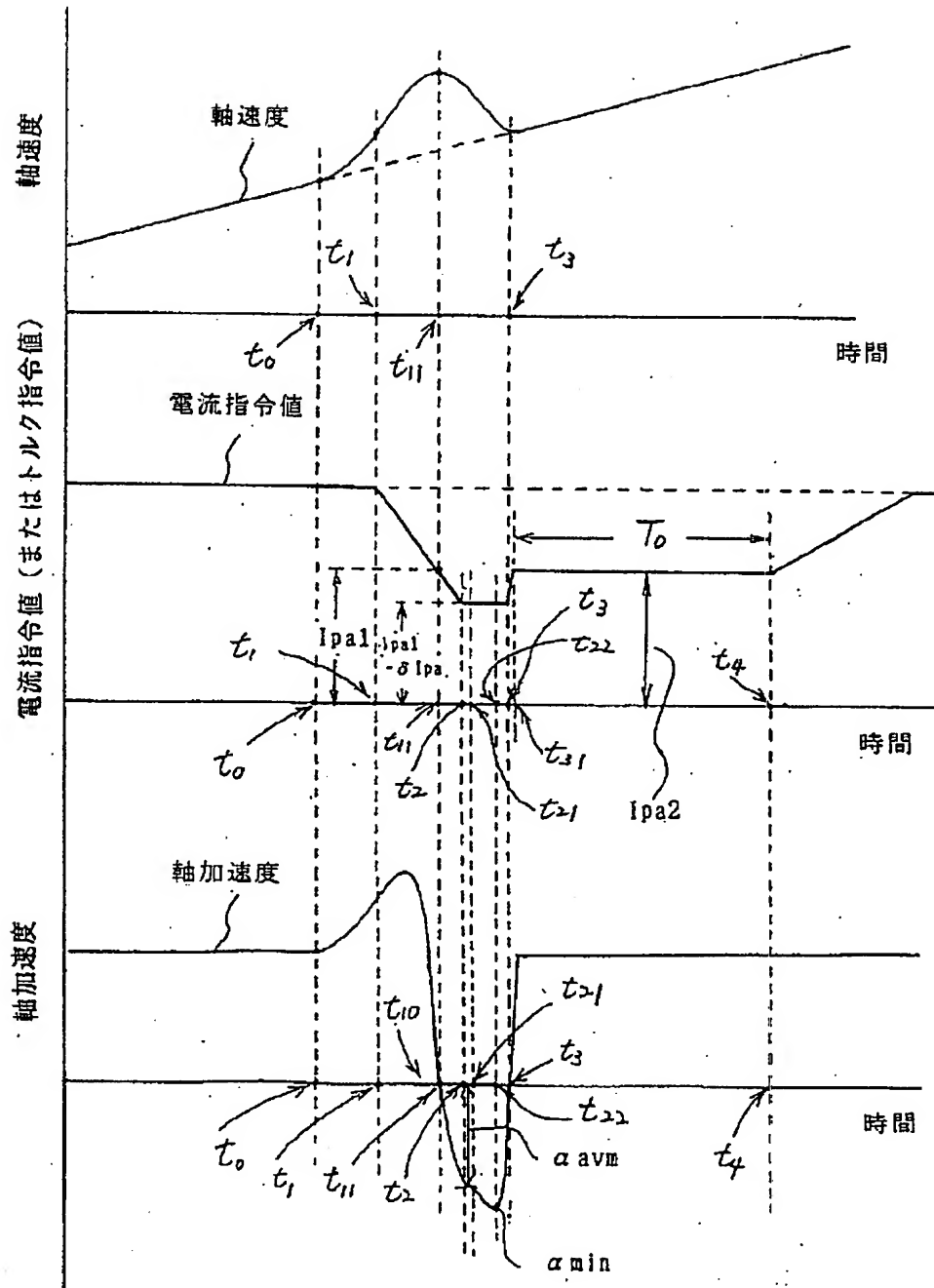
【図3】



【図6】



【図5】



【図 7】

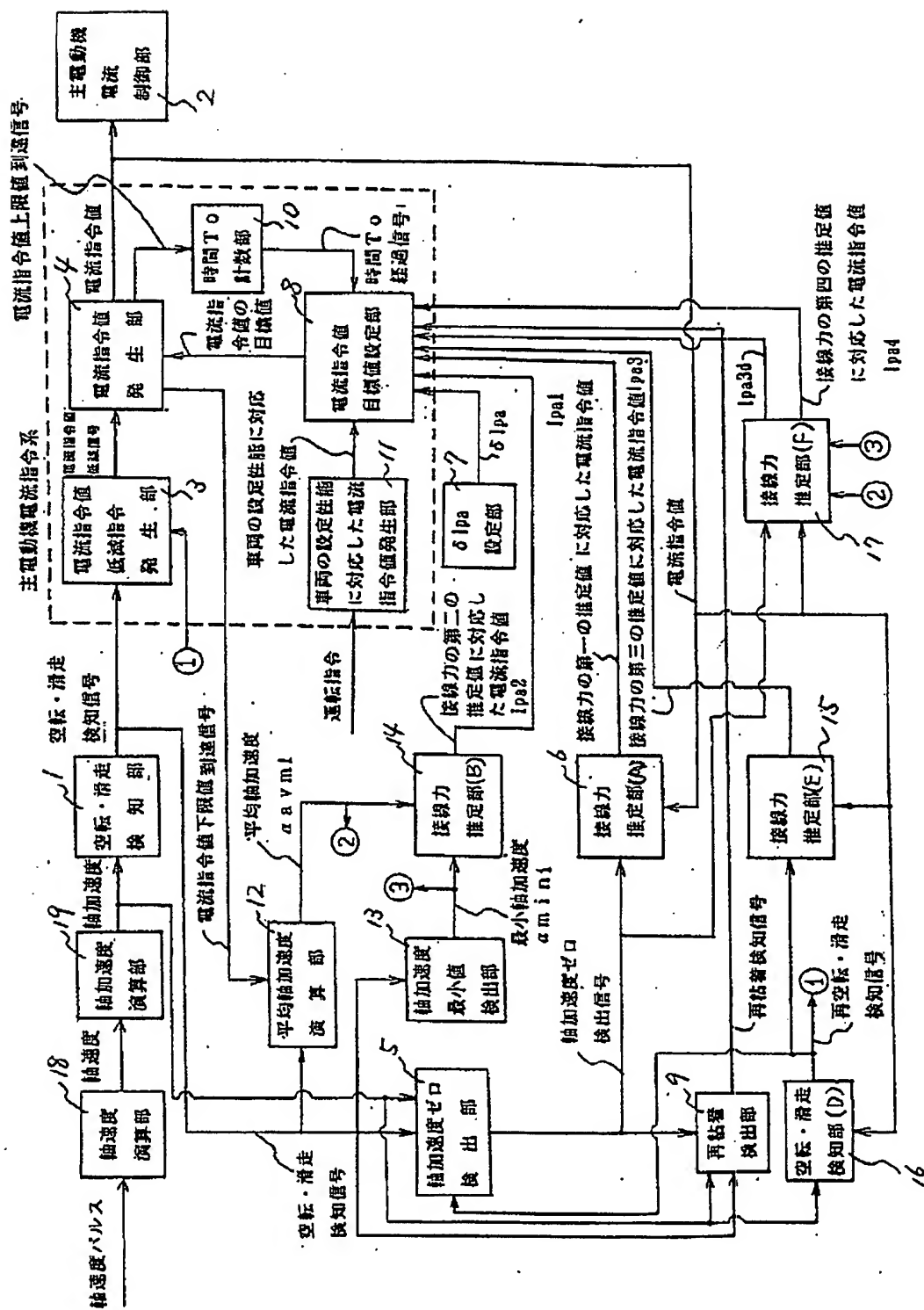
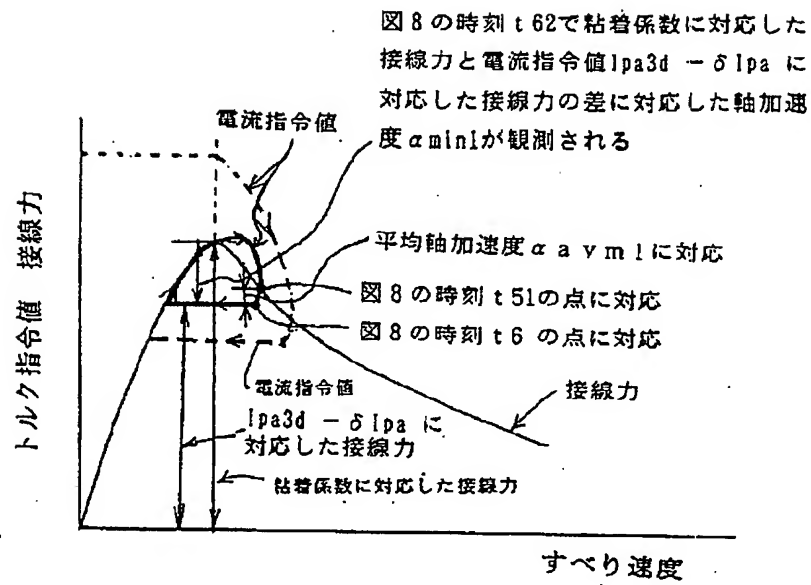


Figure 1 is a multi-axis graph illustrating the relationship between shaft speed, current command, and shaft acceleration over time. The graph is divided into three horizontal sections:

- Top Section (軸速度):** Shows the shaft speed profile. It starts with a ramp-up, followed by a constant speed region, and then a ramp-down. A dashed line indicates a reference speed profile.
- Middle Section (電流指令値 (またはトルク指令値)):** Shows the current command profile. It follows a similar pattern to the speed profile, with a ramp-up, a constant current level, and a ramp-down. Key parameters include:
 - I_{pa1} : Initial current level.
 - $I_{pa1} - \delta I_{pa}$: Current level during the deceleration phase.
 - $I_{pa3d} - \delta I_{pa}$: Current level during the final deceleration phase.
 - I_{pa3d} : Final current level.
 - T_0 : Time interval between the start of the deceleration phase and the final current level.
- Bottom Section (軸加速度):** Shows the shaft acceleration profile. It exhibits peaks and troughs corresponding to the changes in speed and current. Key parameters include:
 - a_{av} : Average acceleration during the deceleration phase.
 - a_{av1} and a_{min1} : Specific acceleration values during the deceleration phase.

Time intervals are marked with t_1 through t_{10} across the three sections, indicating the sequence of events in the control process. A note on the right side of the middle section states: "時間 I_{pa3} と I_{pa4} の小さいほうを選択" (Select the smaller value of time I_{pa3} and I_{pa4}).

【図9】



【図10】

